

# Phased Array Measurements Made on the GE Counter-Rotating Open Rotor Model, F31/A31 Blades

Gary Podboy NASA GRC

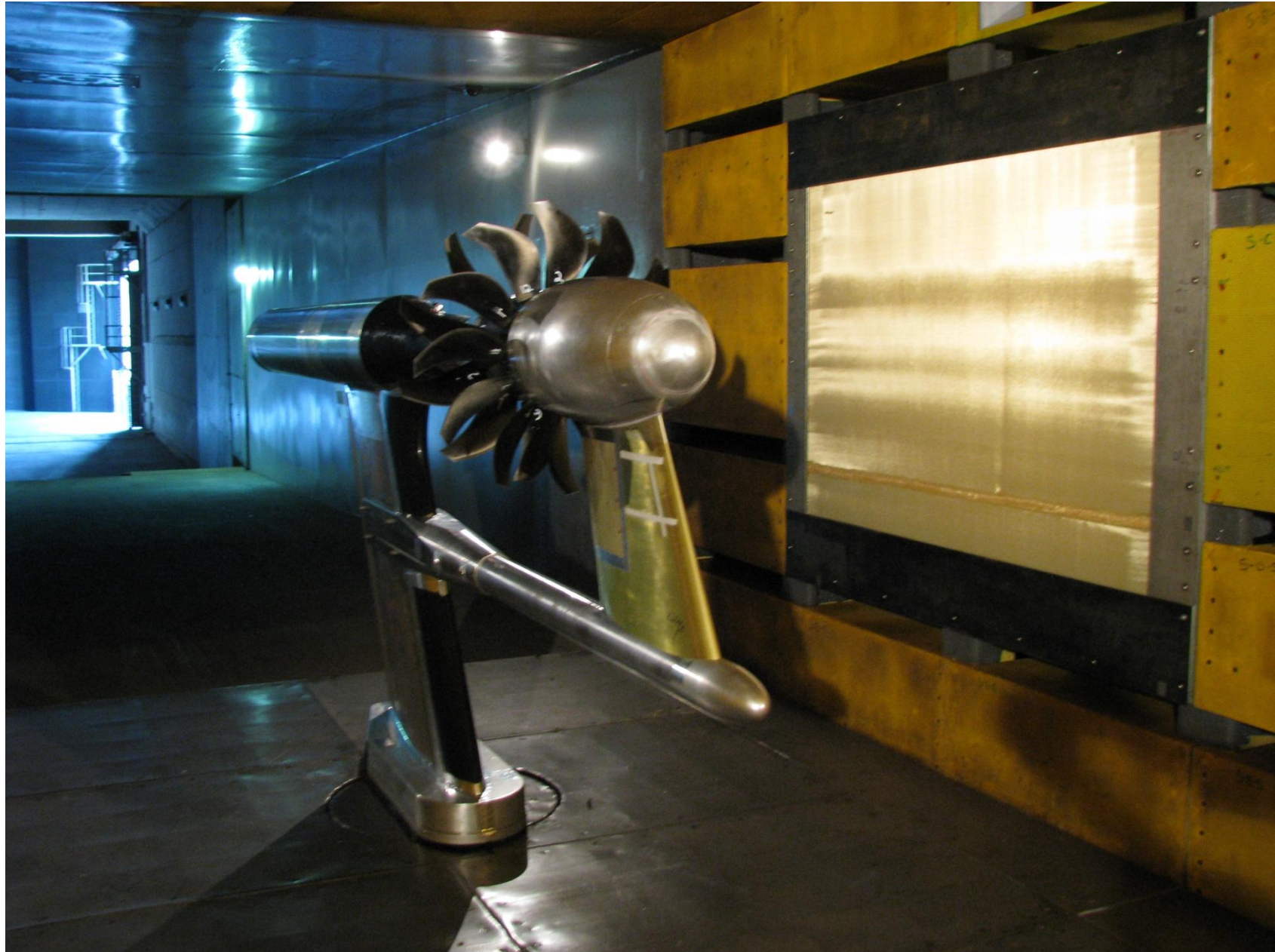
Csaba Horvath ASRC Aerospace

Acoustics Technical Working Group

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Support Provided by the Environmentally Responsible Aviation Program

## GE Counter Rotating Open Rotor Model Installed in the NASA Glenn 9 x 15 Ft Wind Tunnel



# Purpose

Locate the noise sources on the model

3D Schematic of 9 x 15 Ft Wind Tunnel

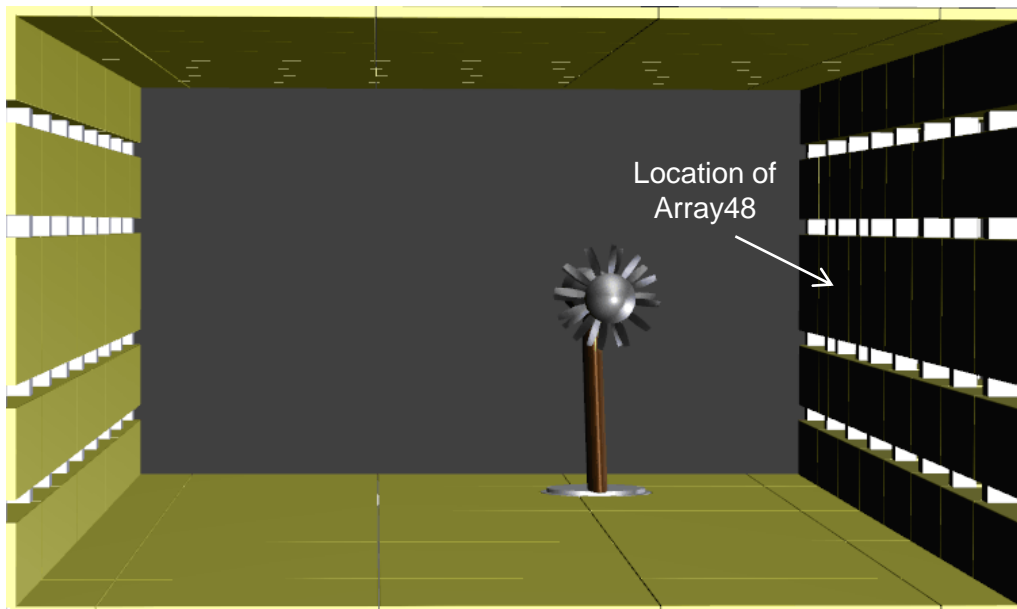
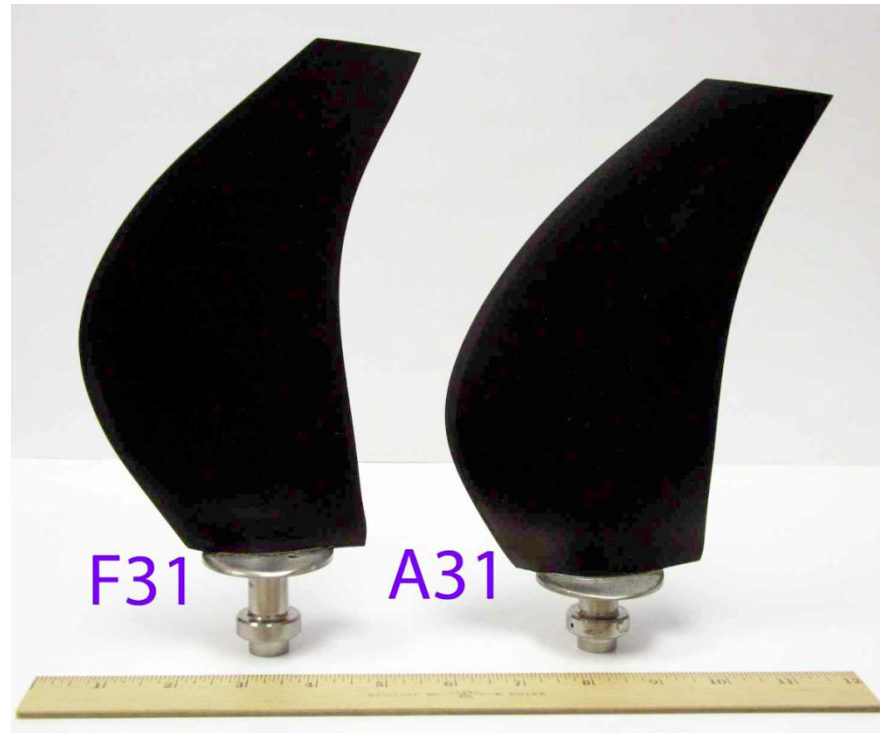


Photo showing Array48 in south wall of Wind Tunnel



## F31/A31 Blades



12 Front Rotor Blades

10 Aft Rotor Blades

Front Rotor Speed = Aft Rotor Speed



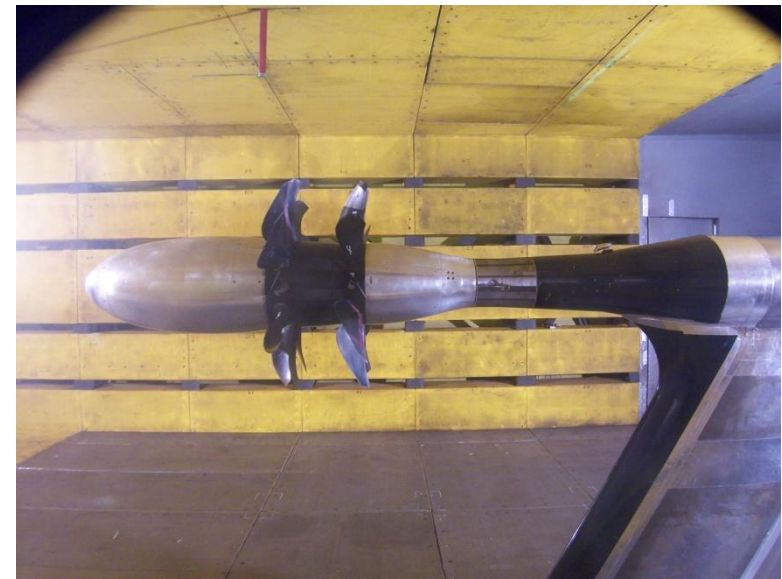
# Test Conditions

Corrected Rotor Speeds, RPM

	Approach Blade Angle (33.5°/35.7°)	Take-off Blade Angle (40.1°/40.8°)
<b>Mach 0.2    0° AOA</b>	5598, 6325, 6773, 7245, 7487	4628, 5277, 5561, 6080, 6316, 6450
<b>Mach 0.2    -3° AOA</b>	5598, 6325, 6773	4628, 5561, 6316
<b>Mach 0.2    -8° AOA</b>	5598, 6325, 6773	4628, 5561, 6316
<b>Mach 0.22    0° AOA</b>	5903, 6617, 7054	4880, 5790, 6530

Front Rotor Speed = Aft Rotor Speed  
 Green designates Approach design speed  
 Red designates Take-off design speed

No Pylon



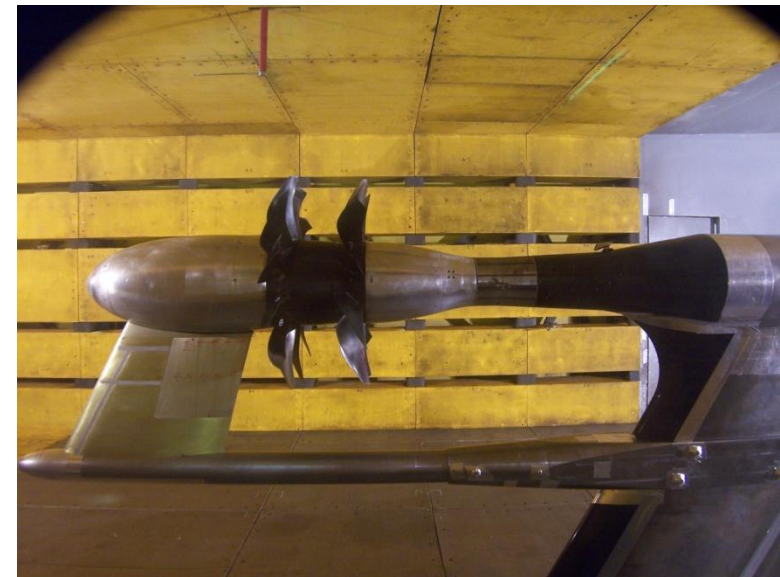
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Pylon

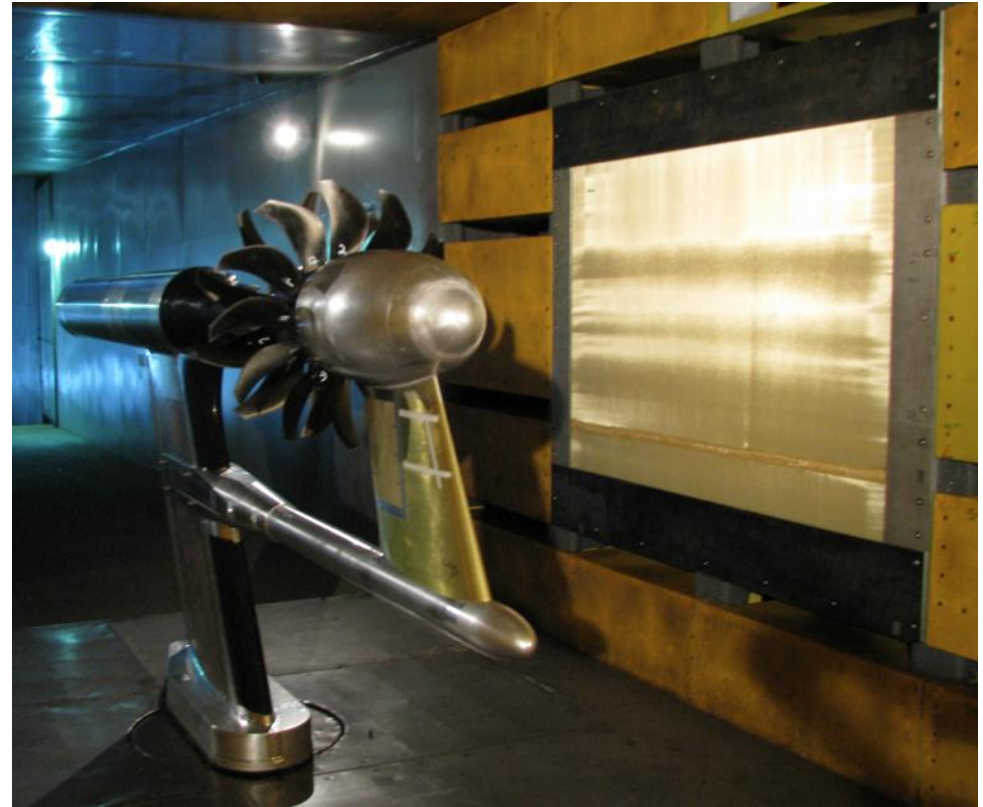


# First Use of Kevlar Window

No Kevlar Window

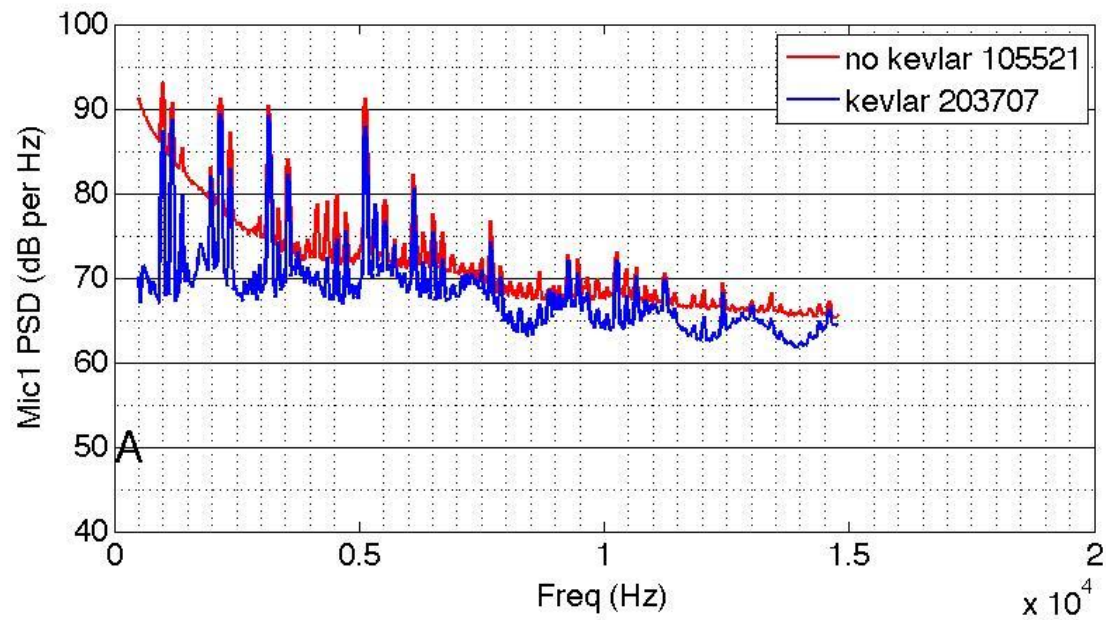


Kevlar Window

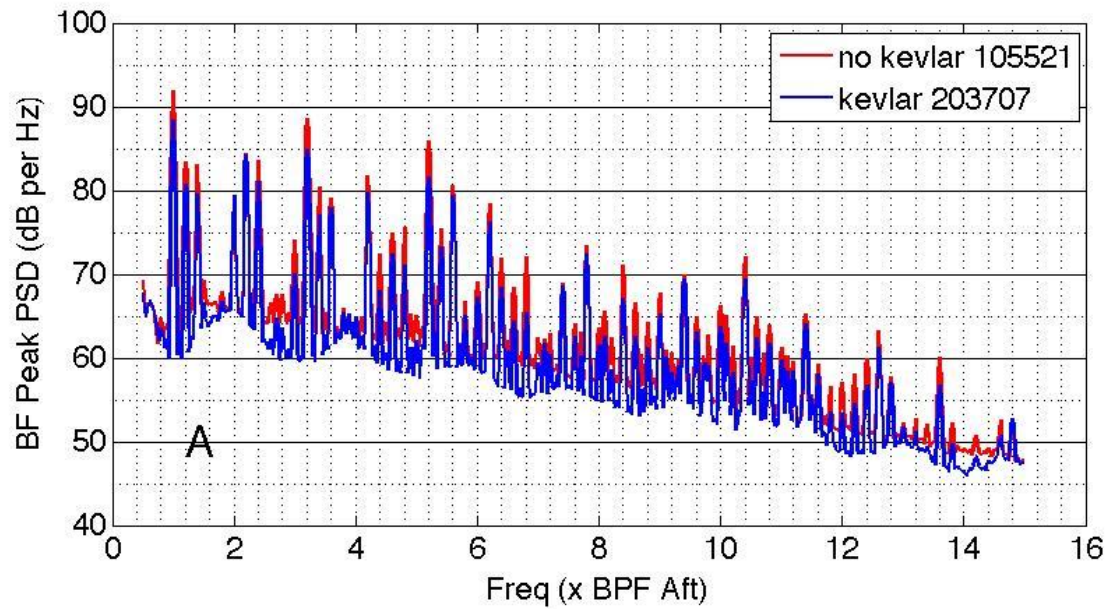




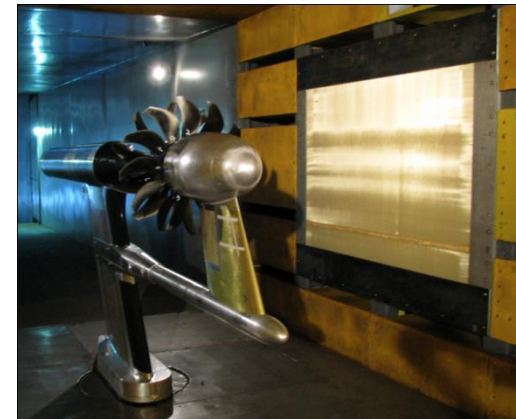
# First Use of Kevlar Window



No Kevlar Window



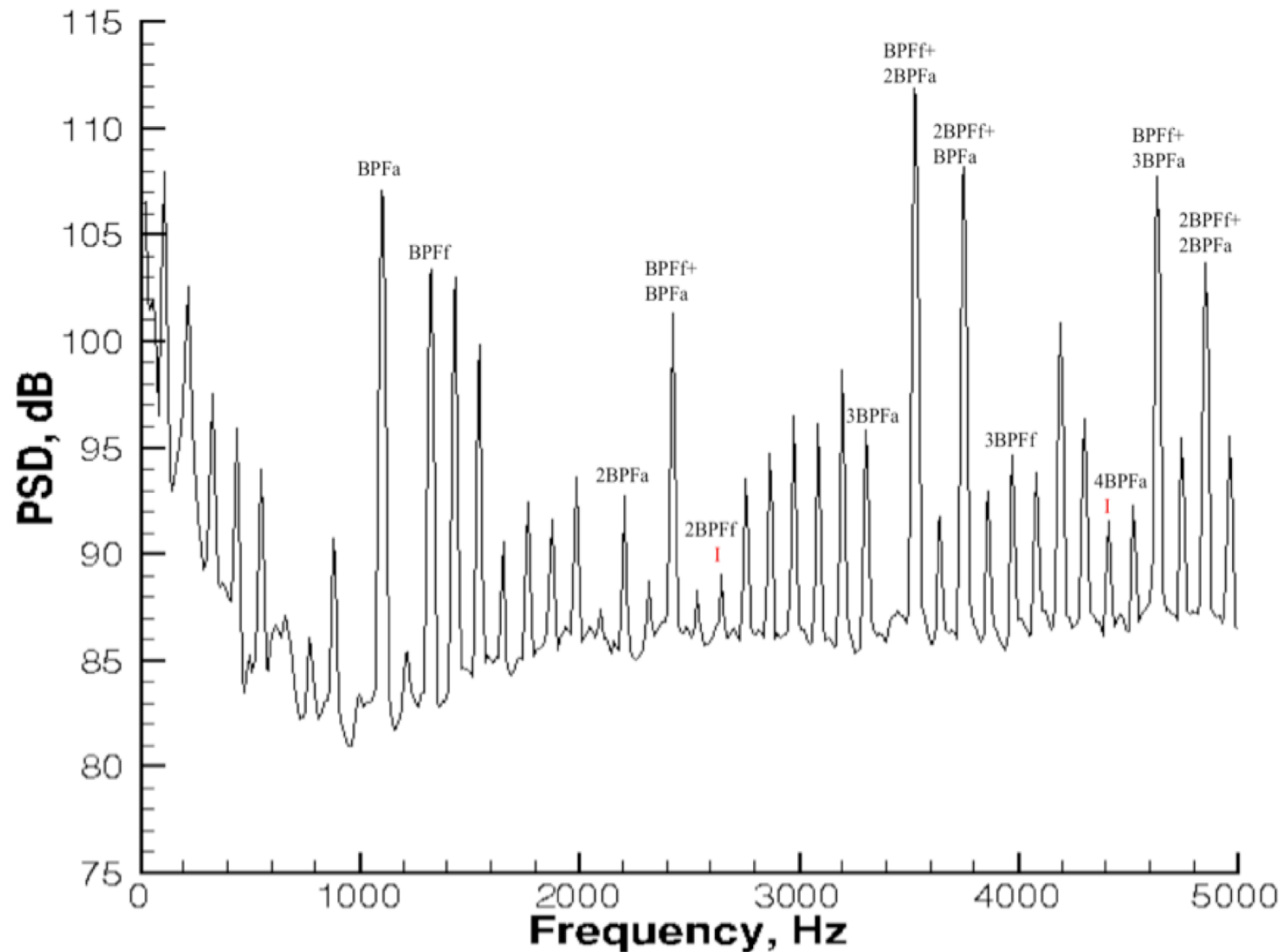
Kevlar Window





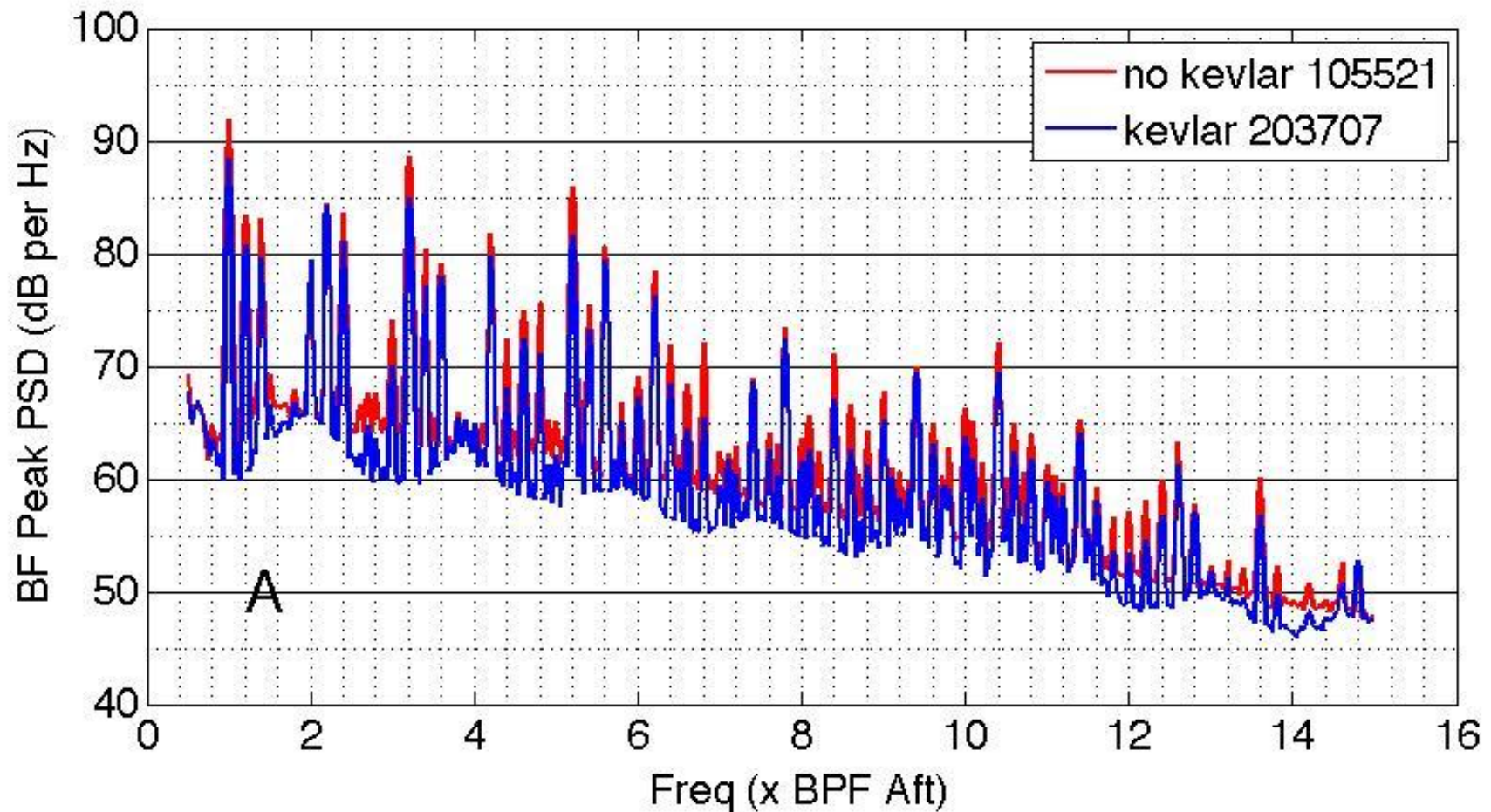
# Data Processing Issues

*Want to determine source location of each tone and the broadband noise between the tones*



# Data Processing Issues

Data processed between  
0.5 BPFA and 15 BPFA



# Data Processing Issues

Data processed between 0.5 BPFA and 15 BPFA

using bin widths that varied with RPM  
(5 frequency bins between consecutive shaft orders)

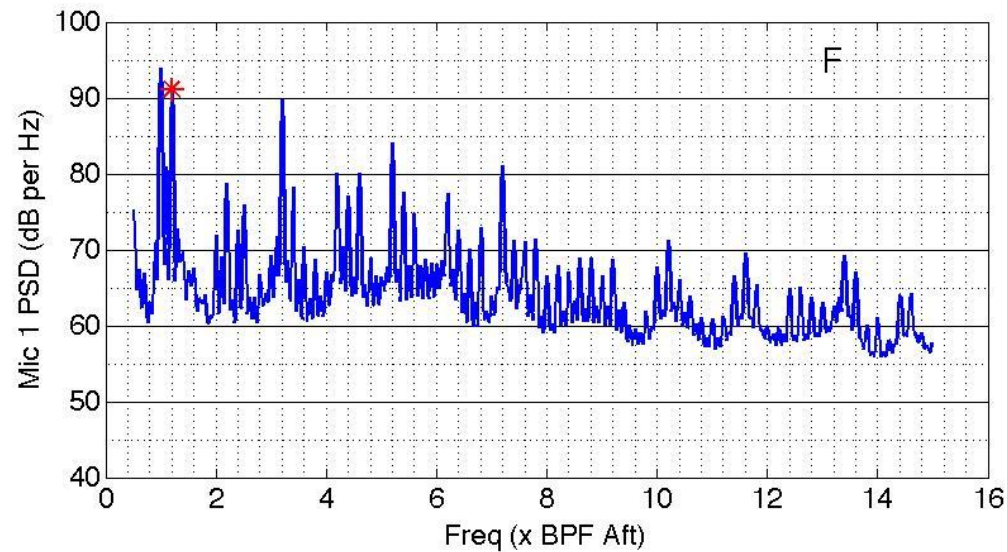
725 beamforming images per set

shaft order processing makes it easier to find images corresponding to certain tones



# Data Processing Issues

## Are the source locations accurate?



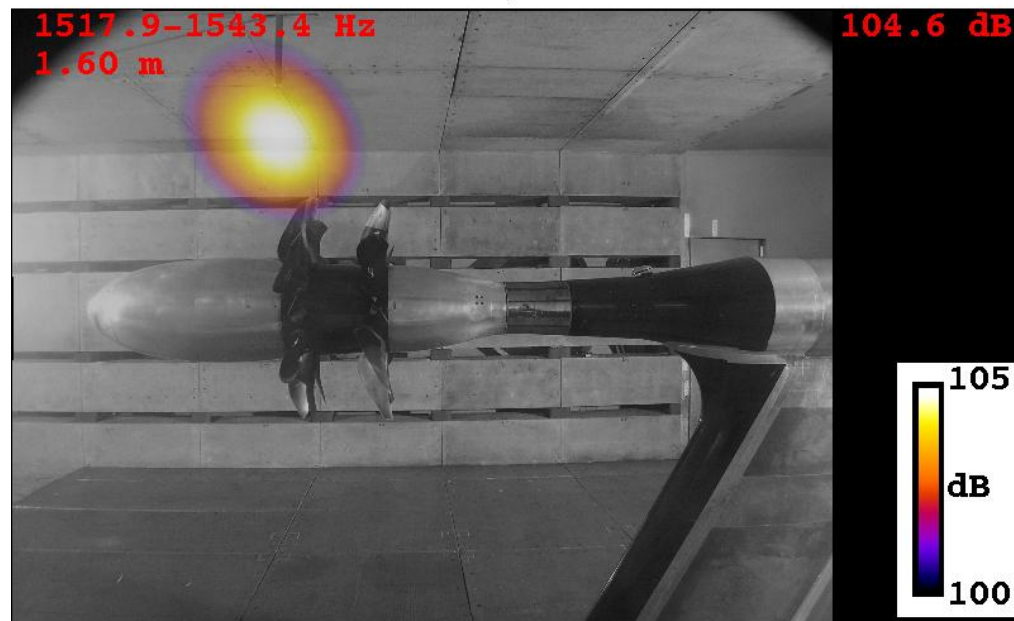
BPFF tone

7487 RPMC

Approach Blade  
Angle Setting

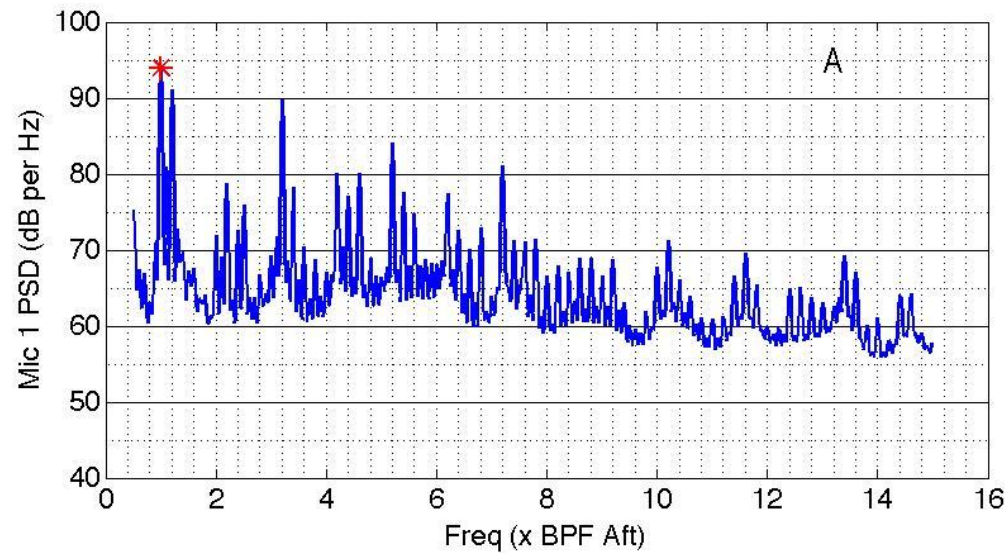
M=0.2

0° AOA



# Data Processing Issues

## Are the source locations accurate?



BPFA tone

7487 RPMC

Approach Blade  
Angle Setting

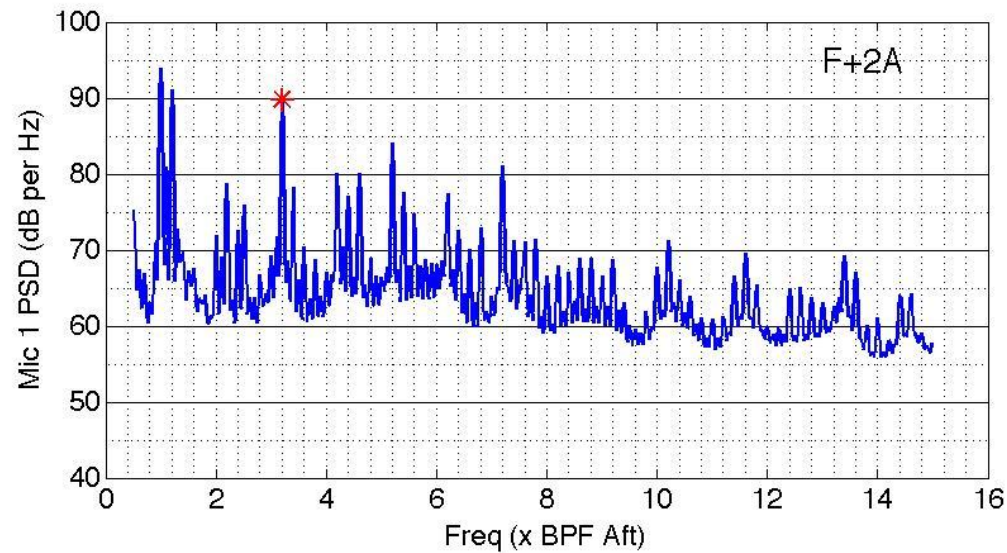
M=0.2

0° AOA



# Data Processing Issues

## Are the source locations accurate?



F+2A tone

7487 RPMC

Approach Blade  
Angle Setting

M=0.2

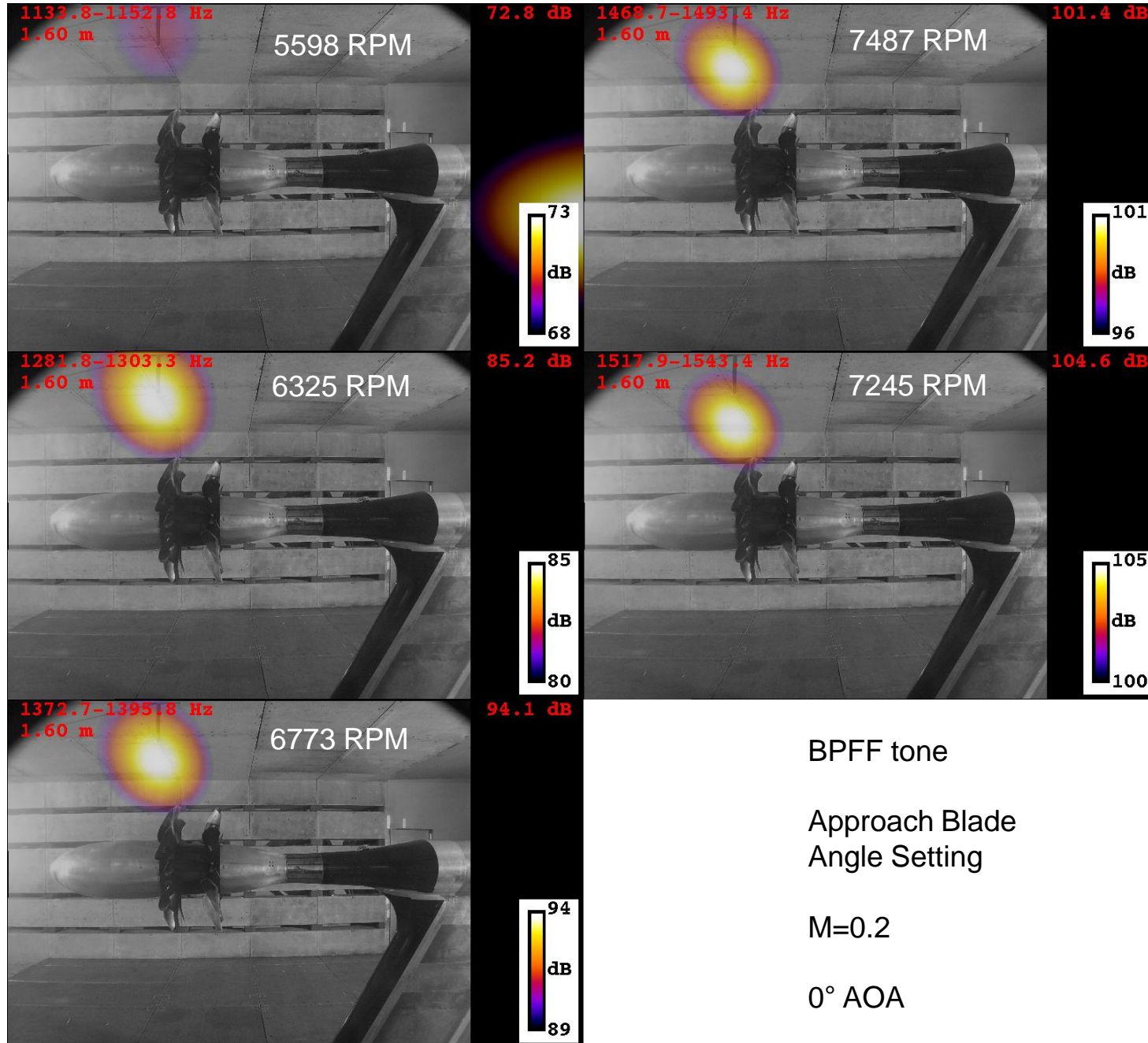
0° AOA





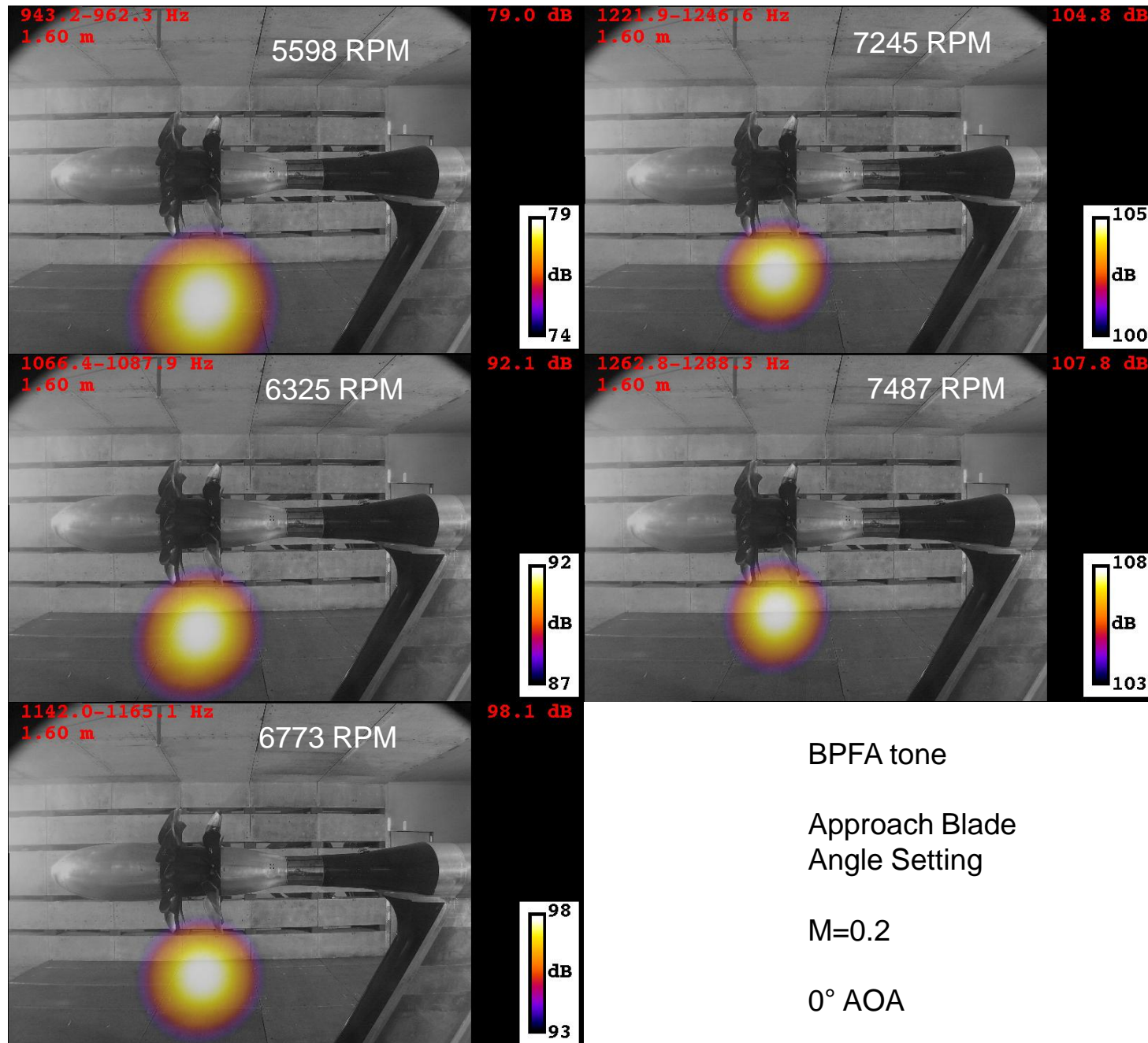
# Data Processing Issues

## Are the source locations accurate?



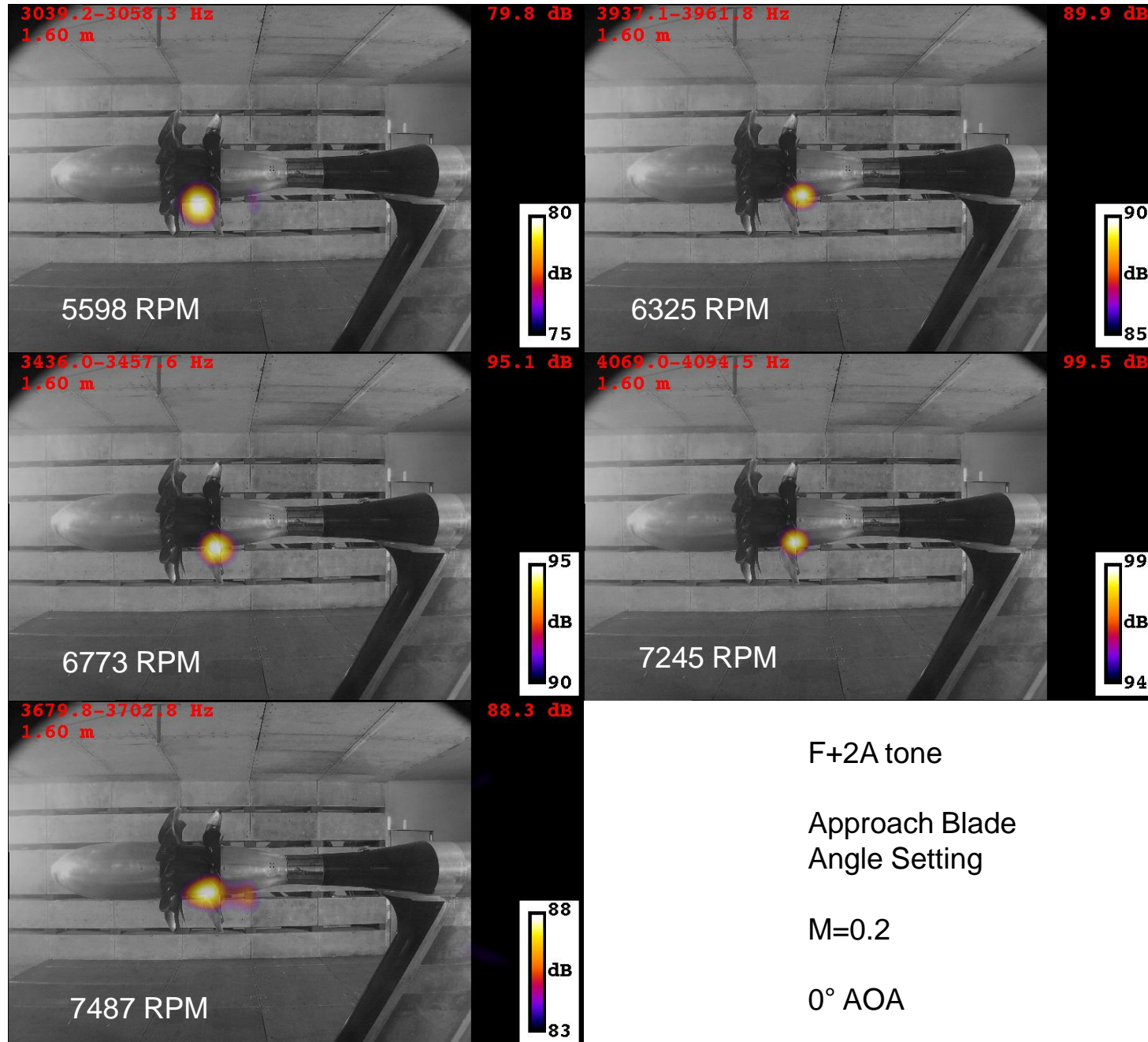
# Data Processing Issues

## Are the source locations accurate?



# Data Processing Issues

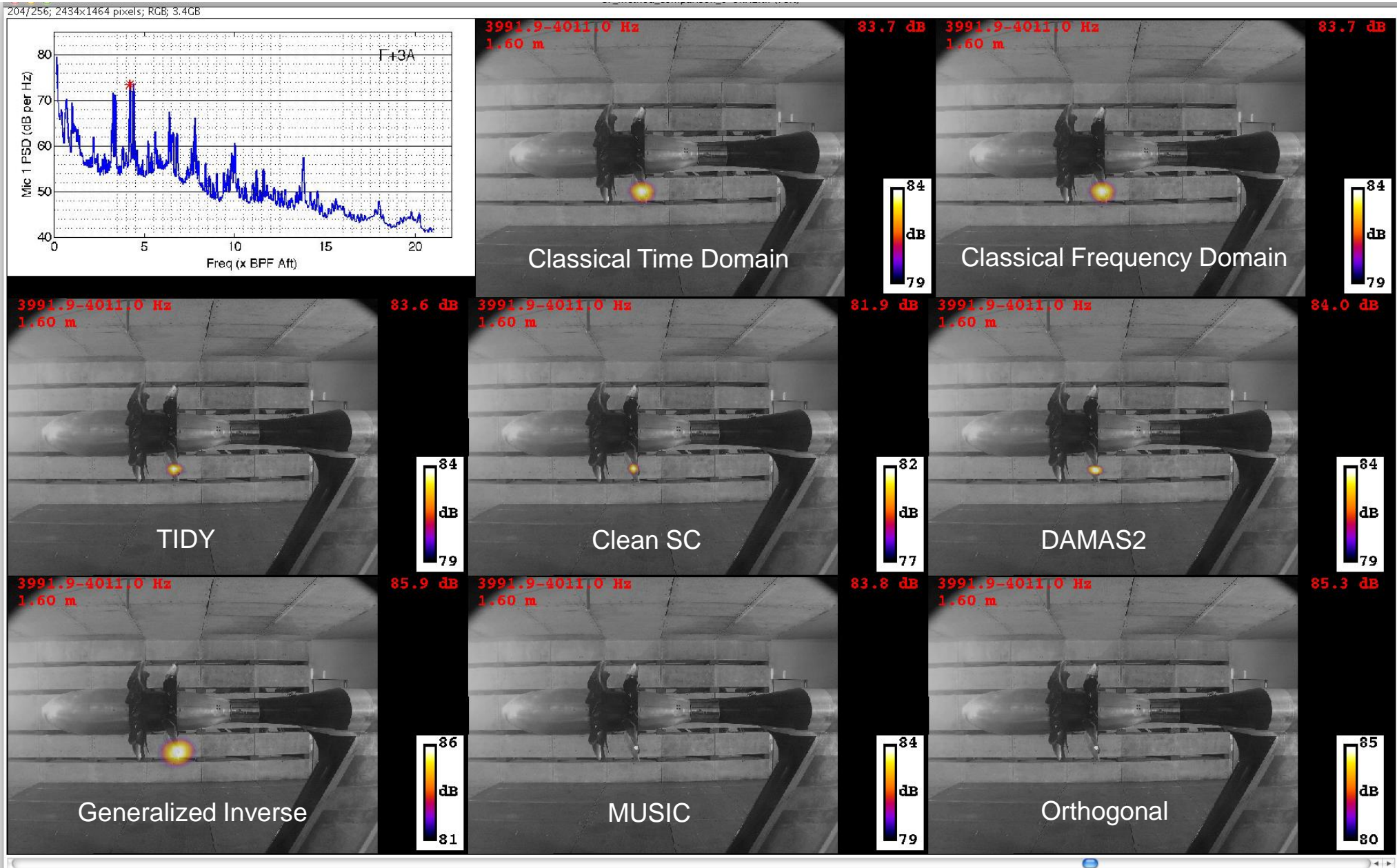
## Are the source locations accurate?





# Data Processing Issues

## Are the source locations accurate?



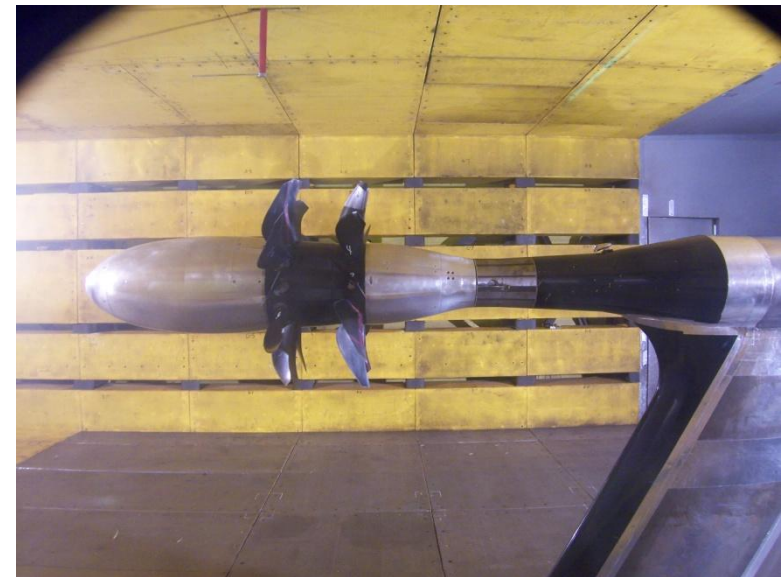
# Test Conditions

Corrected Rotor Speeds, RPM

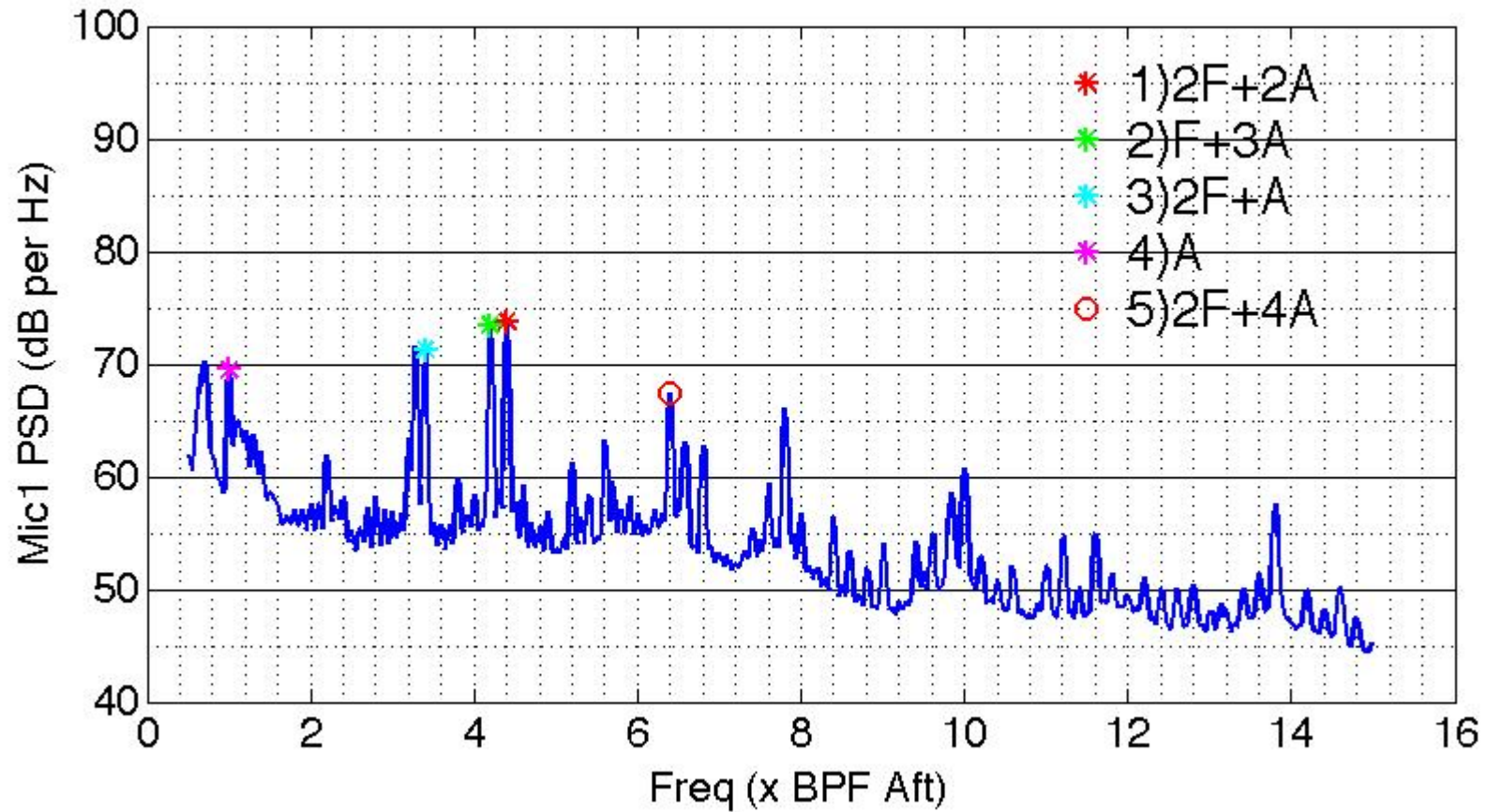
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Front Rotor Speed = Aft Rotor Speed  
 Green designates Approach design speed  
 Red designates Take-off design speed

No Pylon

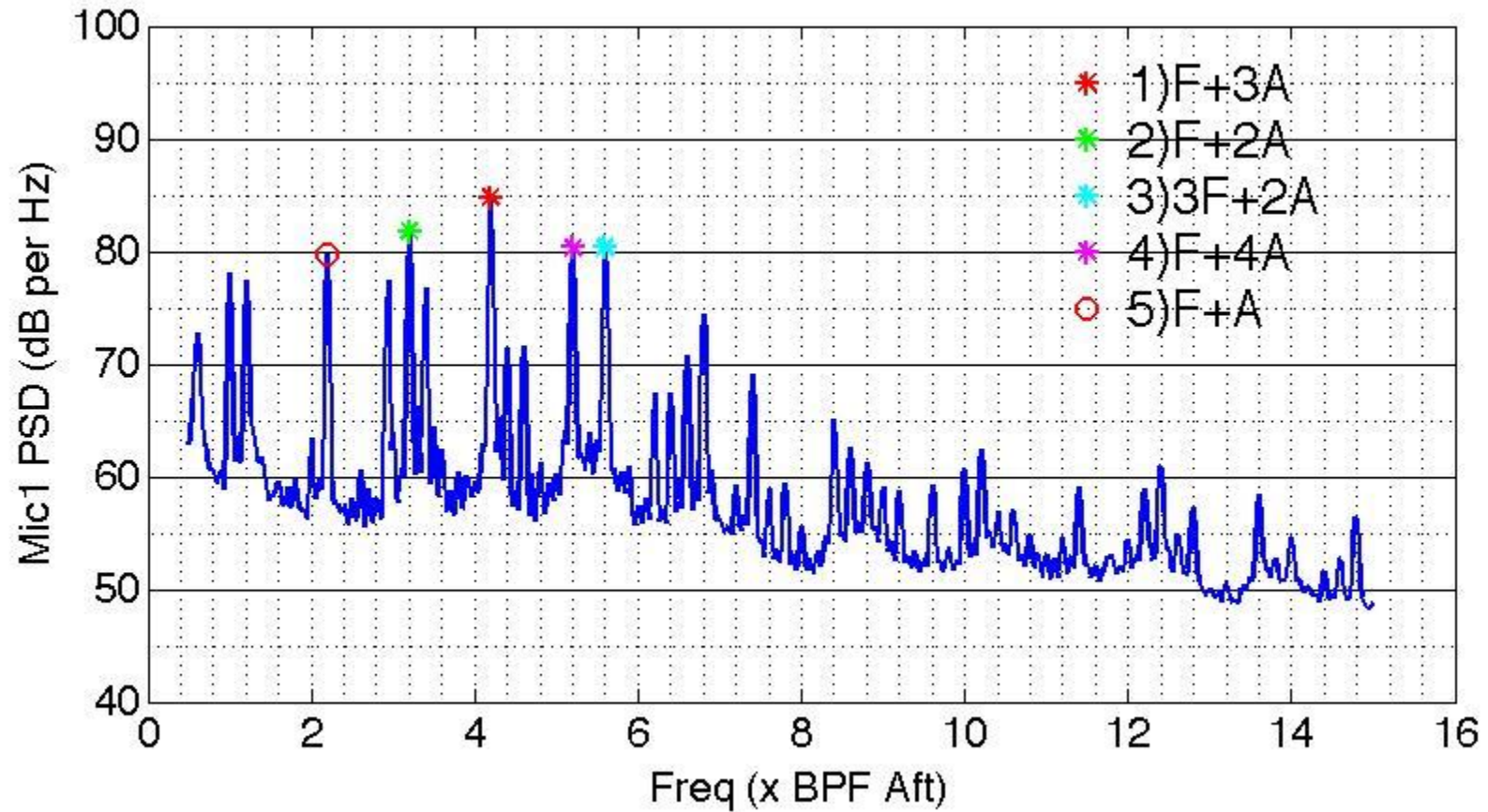


5598 RPM  
M=0.2, 0° AOA, no pylon, Approach



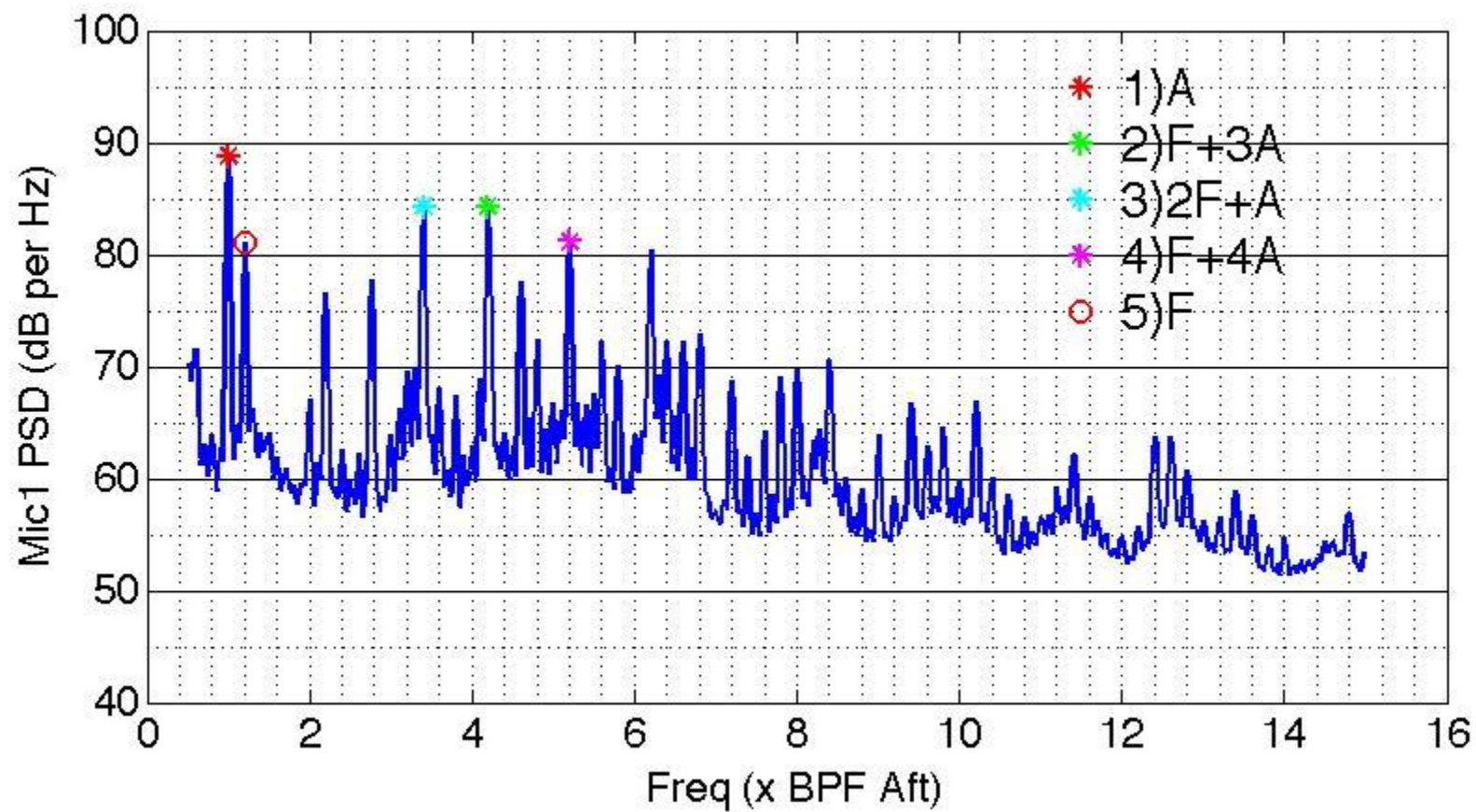


6325 RPM  
M=0.2, 0°AOA, no pylon, Approach

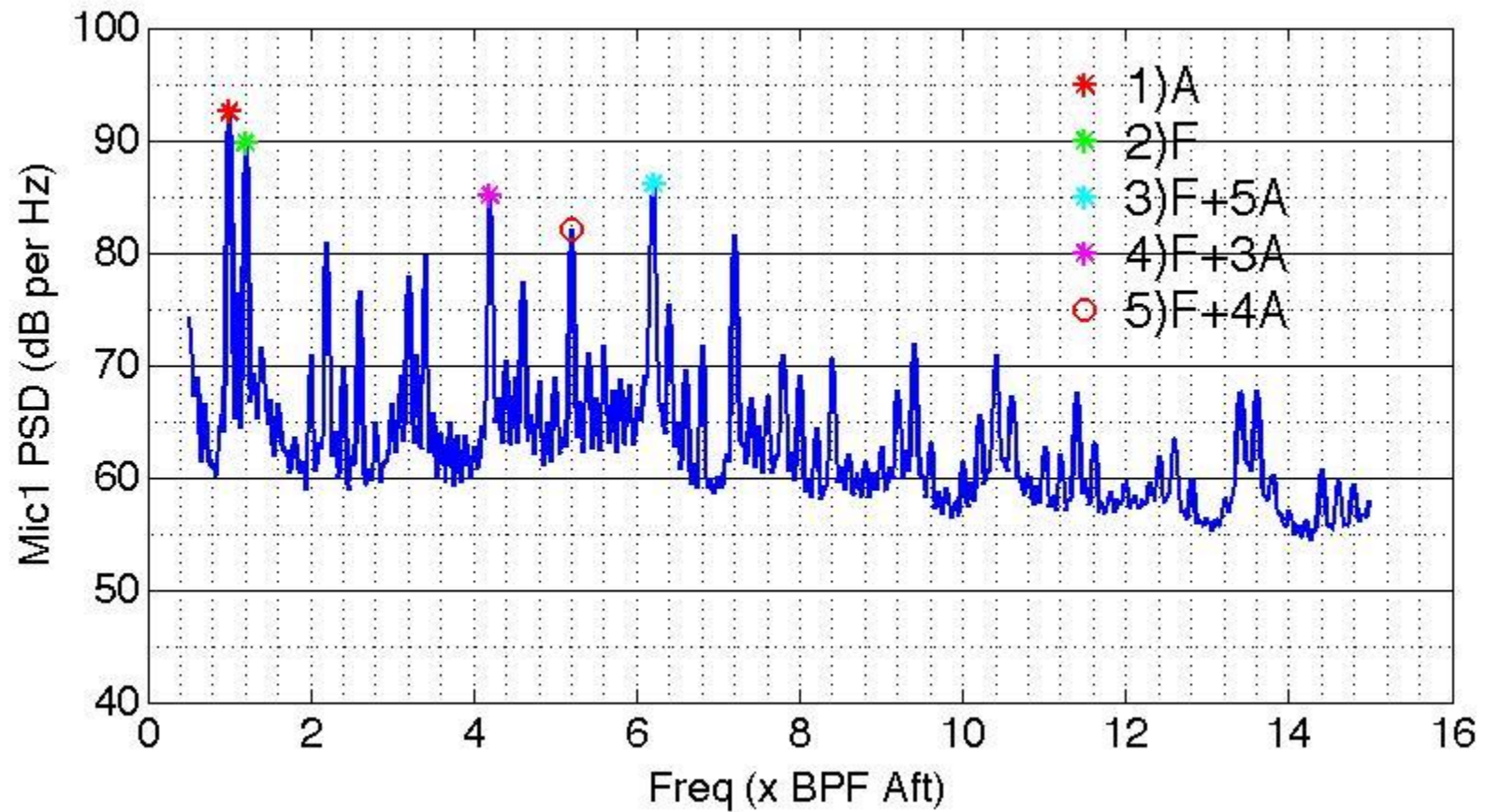




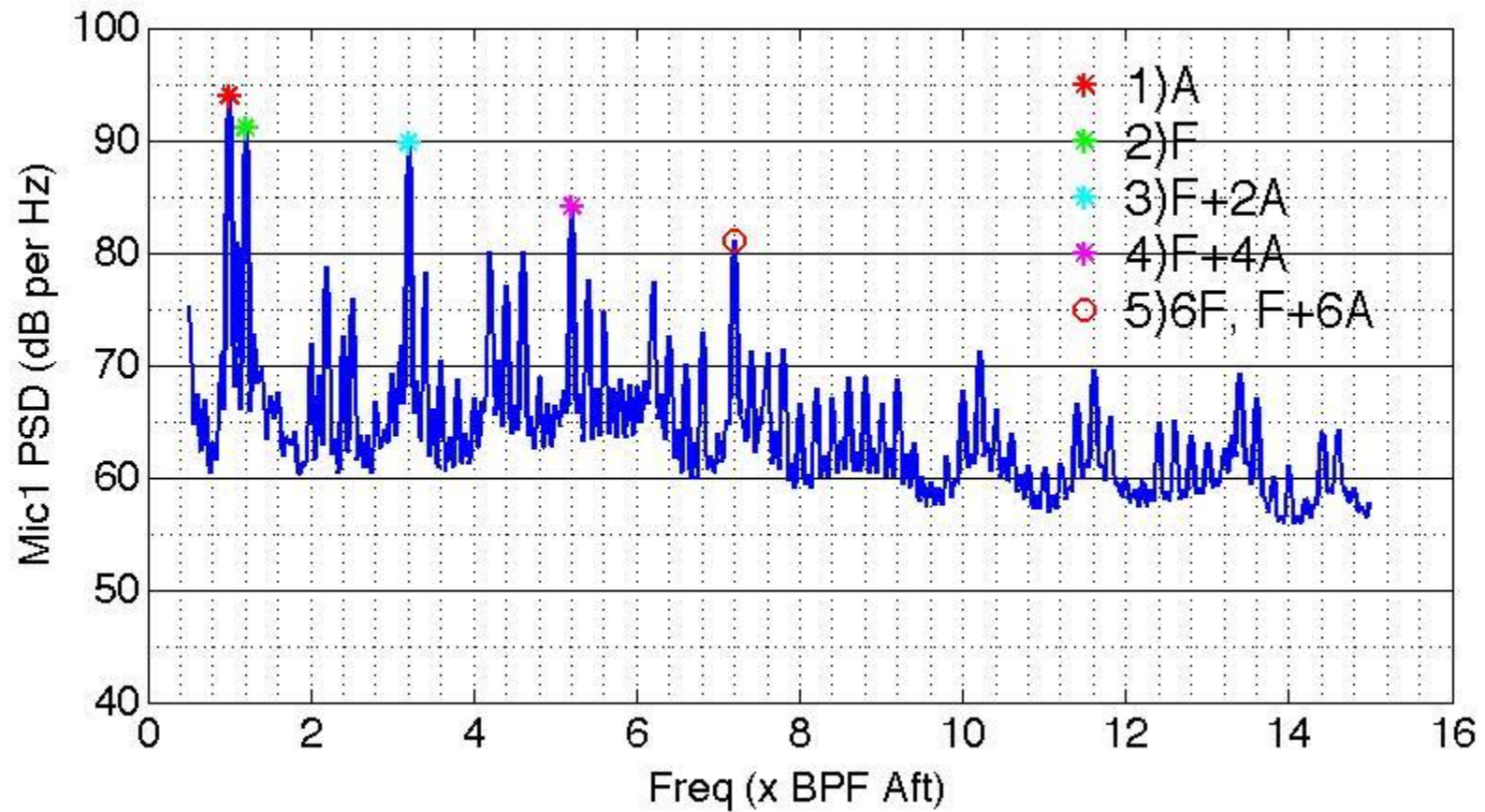
6773 RPM  
M=0.2, 0°AOA, no pylon, Approach



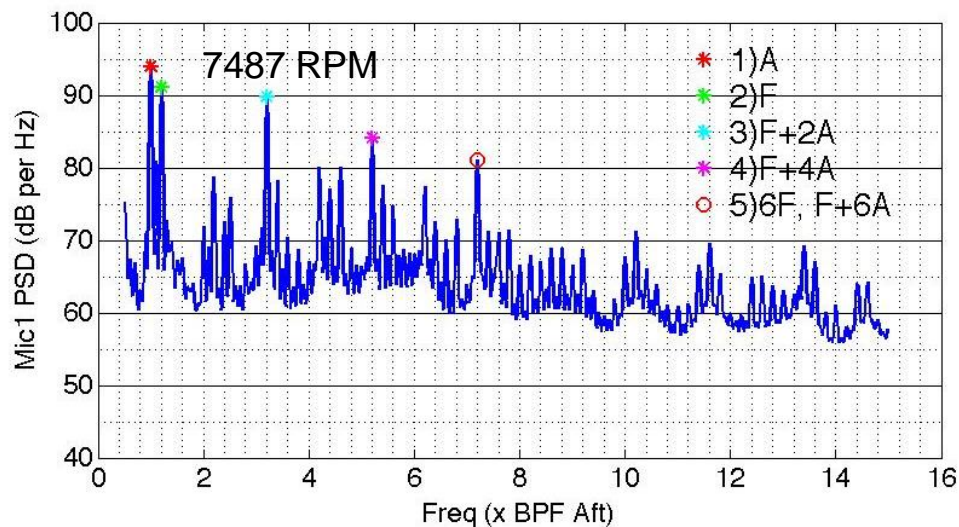
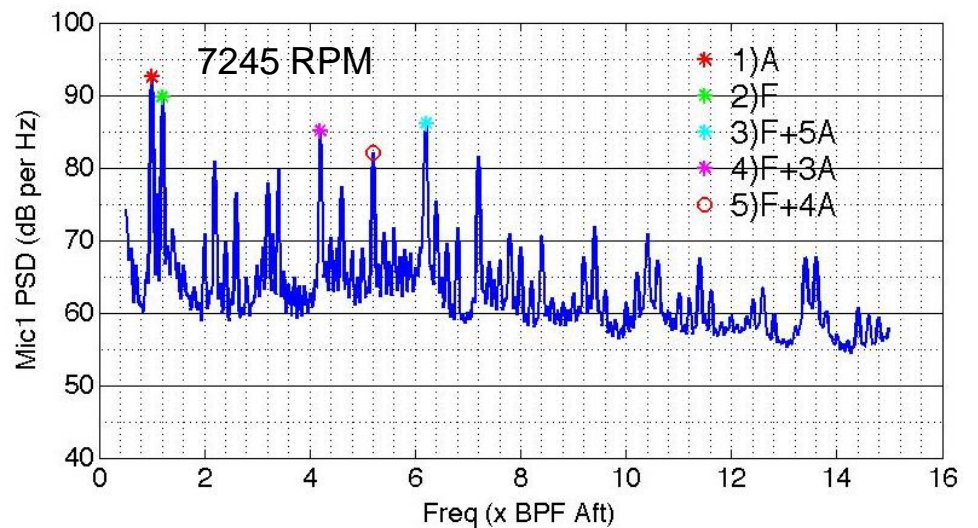
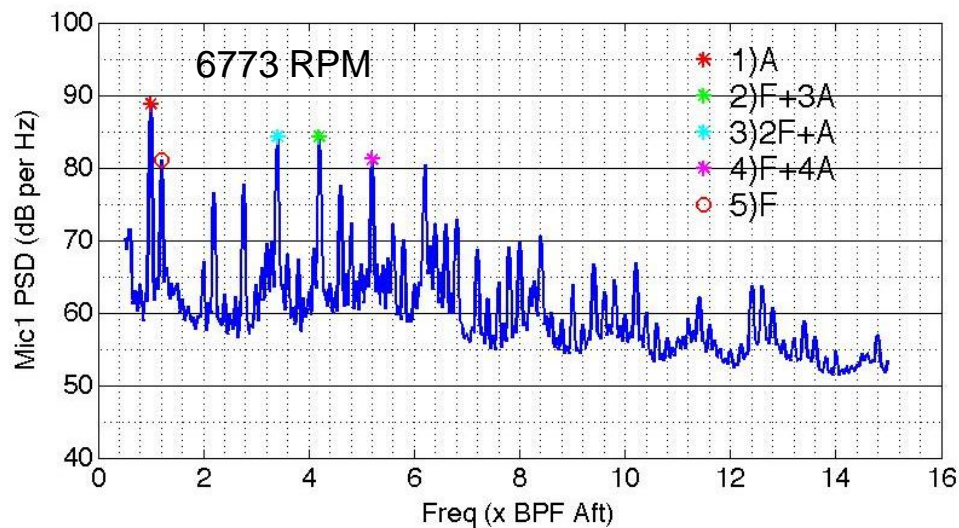
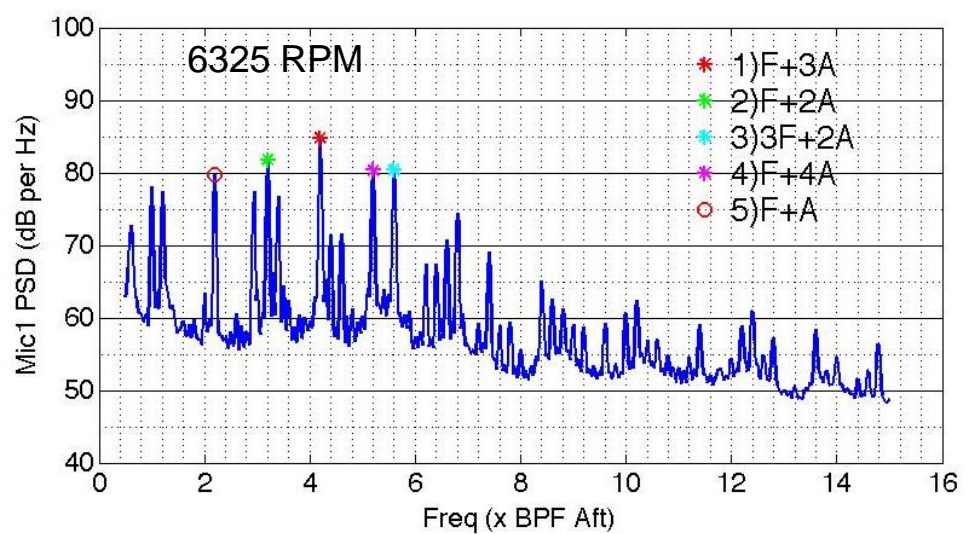
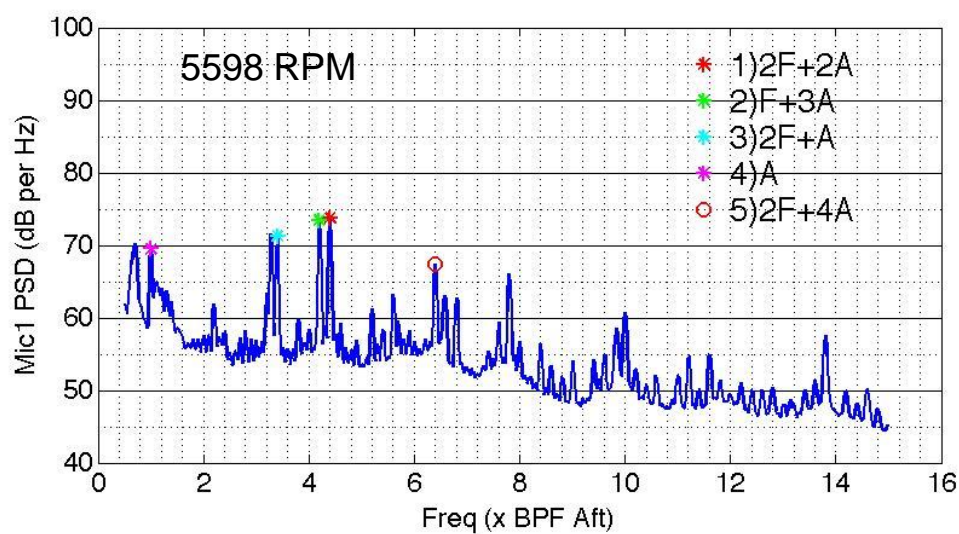
7245 RPM  
M=0.2, 0° AOA, no pylon, Approach



7487 RPM  
M=0.2, 0°AOA, no pylon, Approach







BPF tones become more important as HP increases

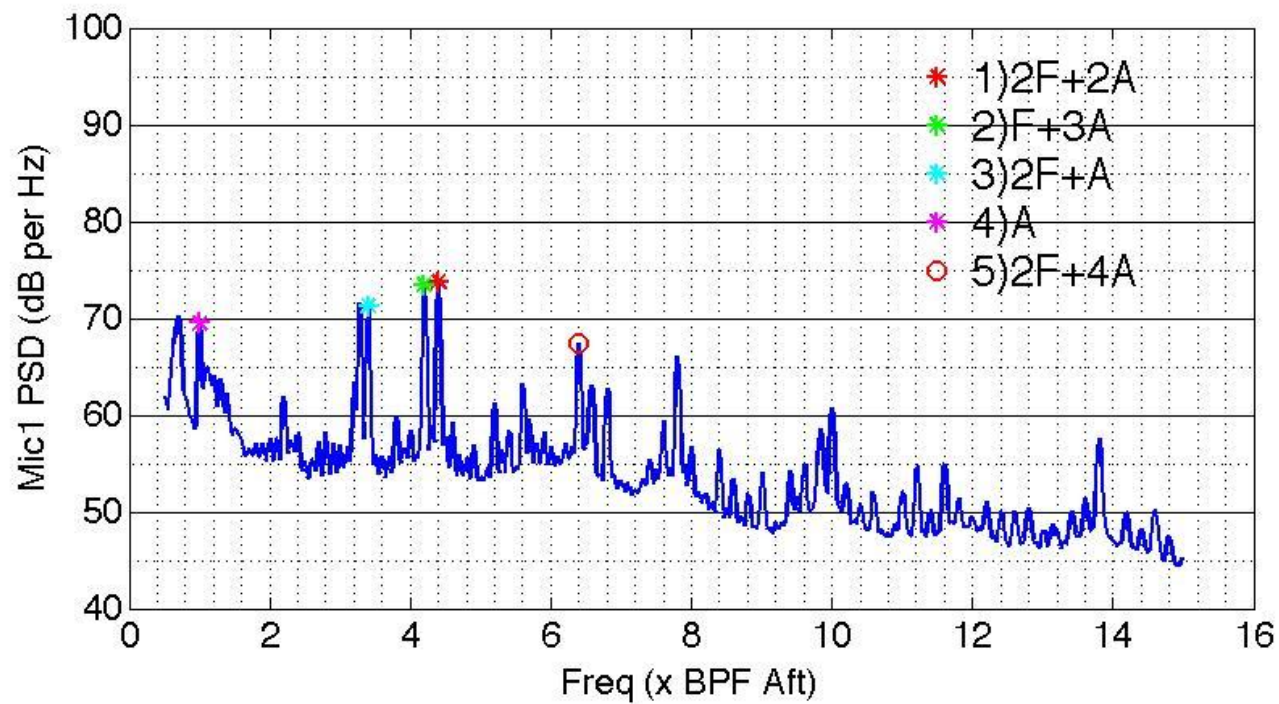
BPFA > BPFF

At high HP, F+xA interaction tones are important



# Noise source location of dominant tones

M=0.2, 0° AOA, no pylon, Approach, varying HP

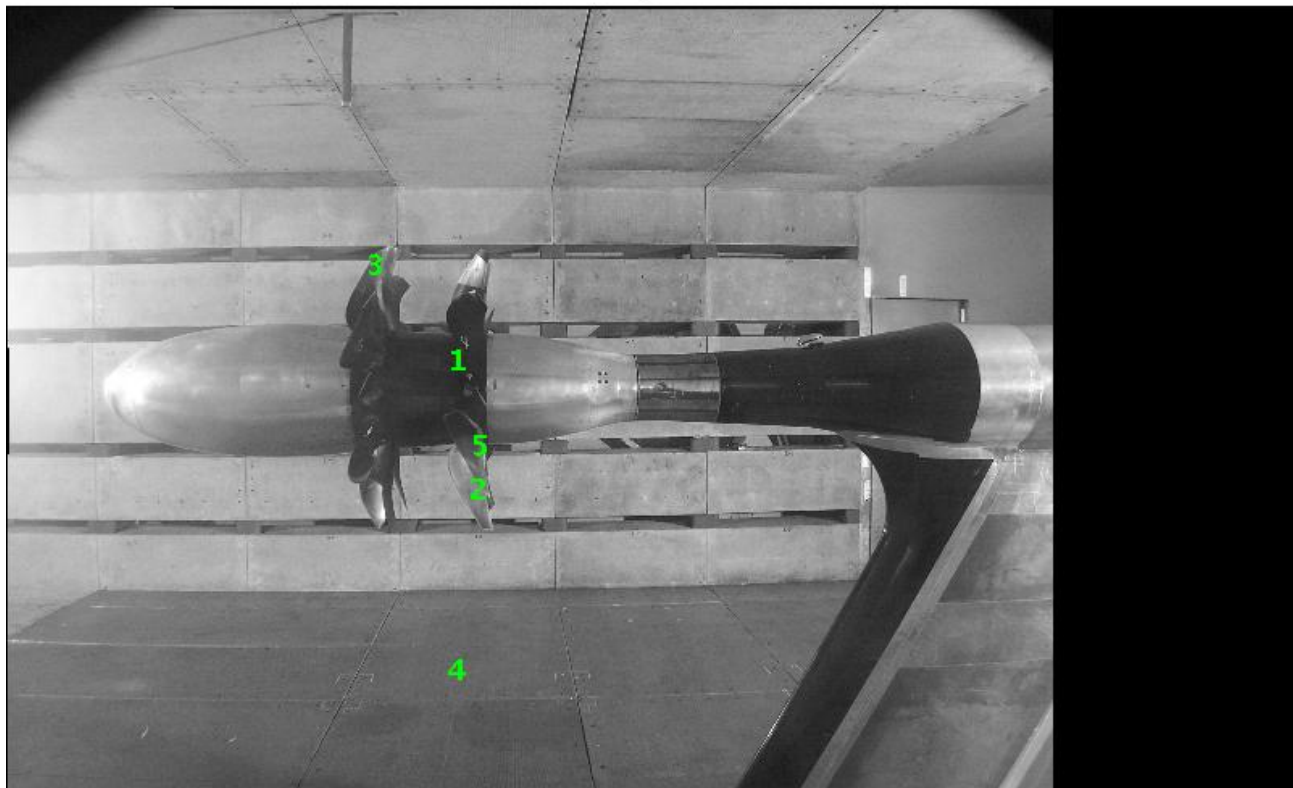


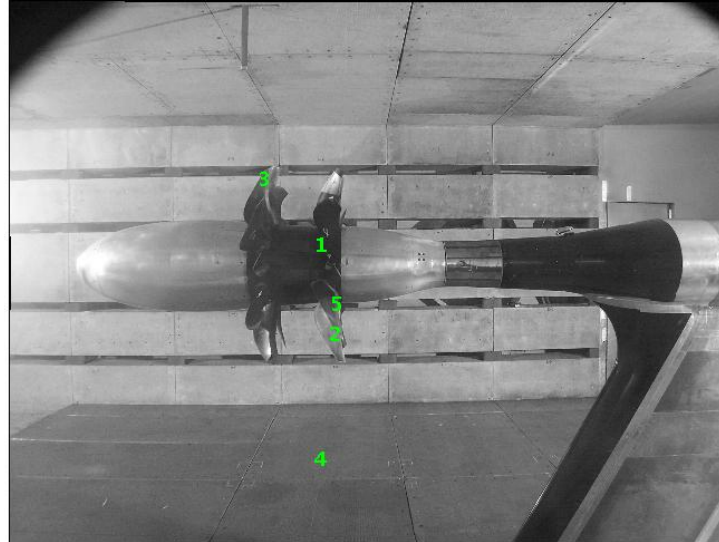
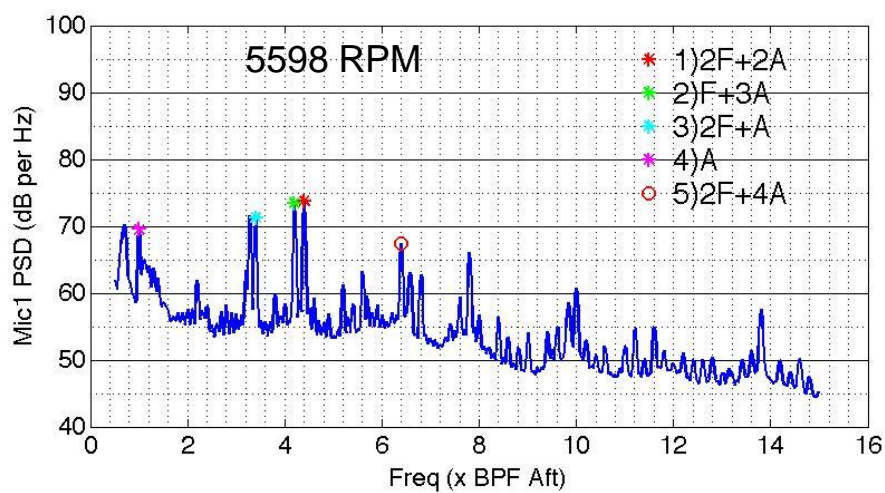
5598 RPM

M=0.2

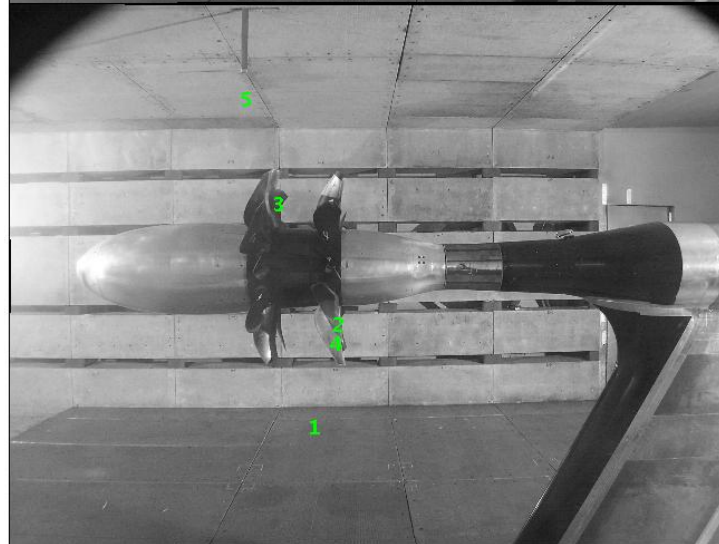
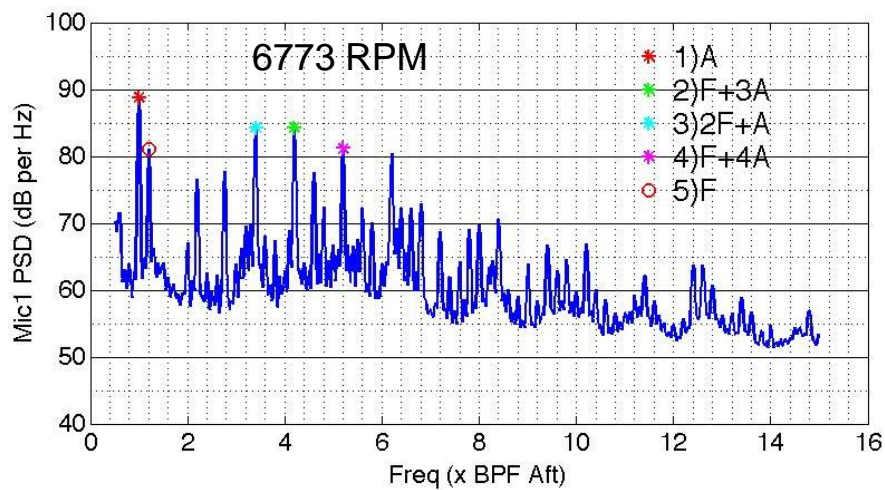
0° AOA

no pylon  
Approach

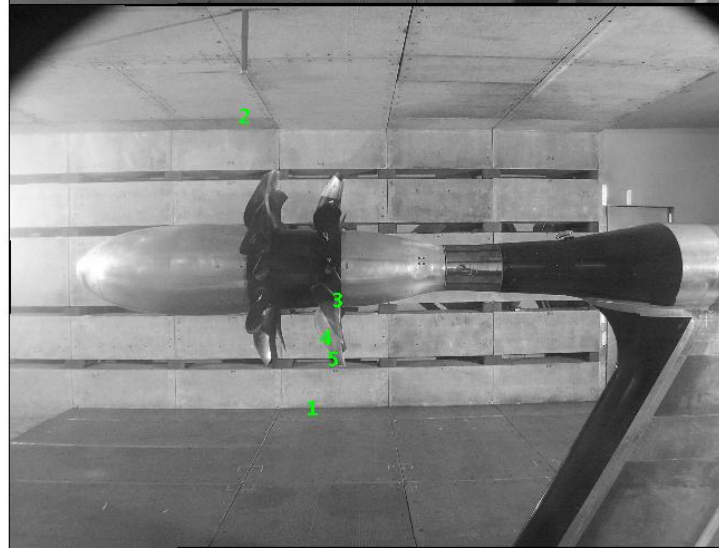
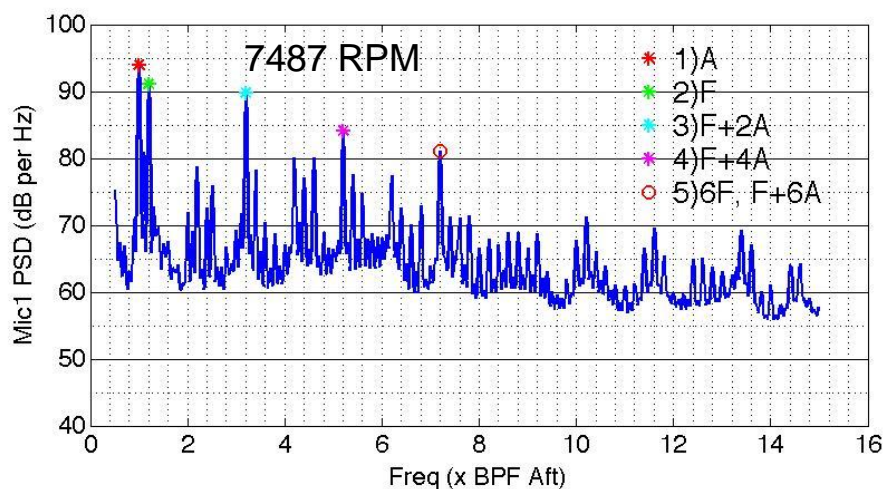




-The dominant tones are, for the most part, located on the side of the rig where the blade is rotating toward the phased array.



-A large percentage of the dominant tones are located on the aft rotor



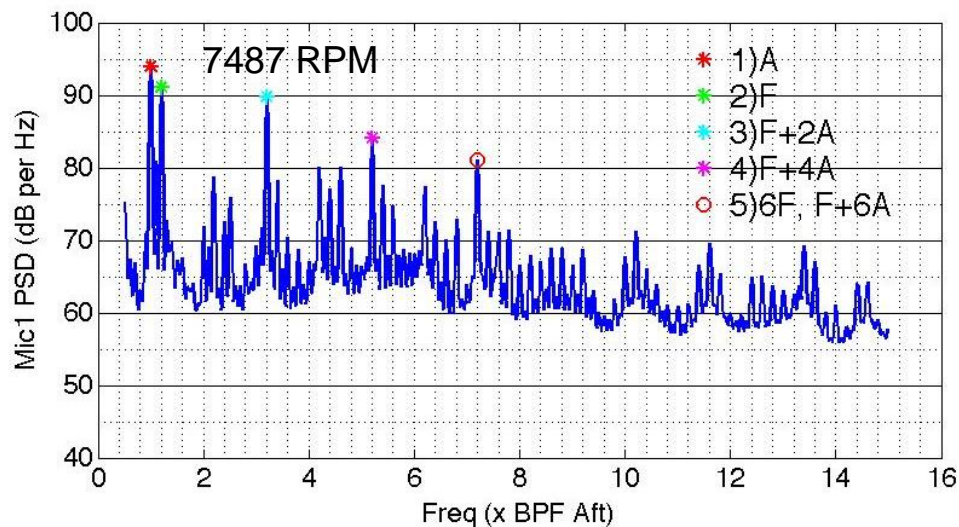
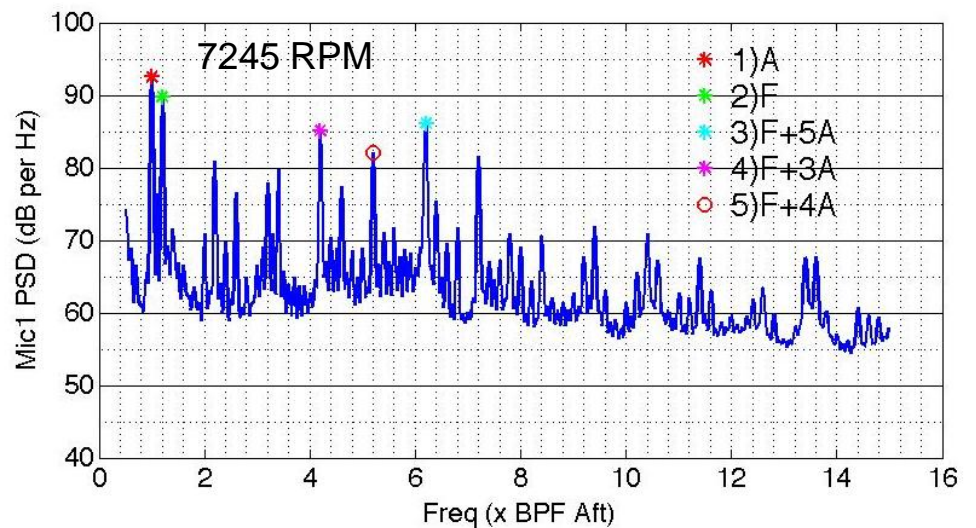
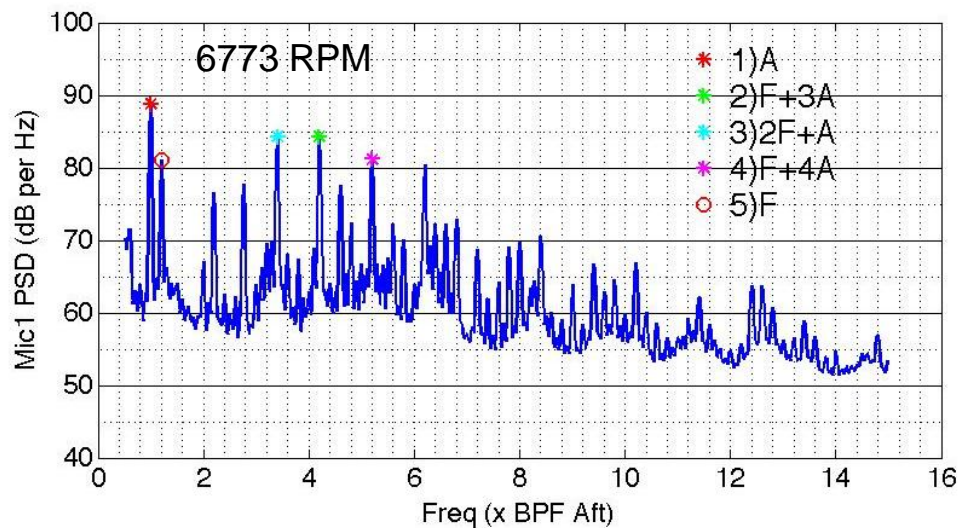
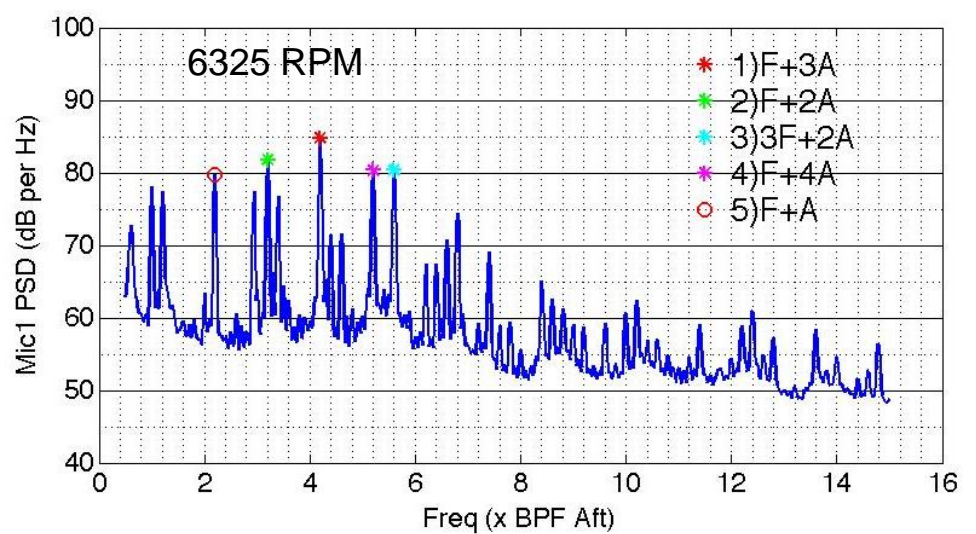
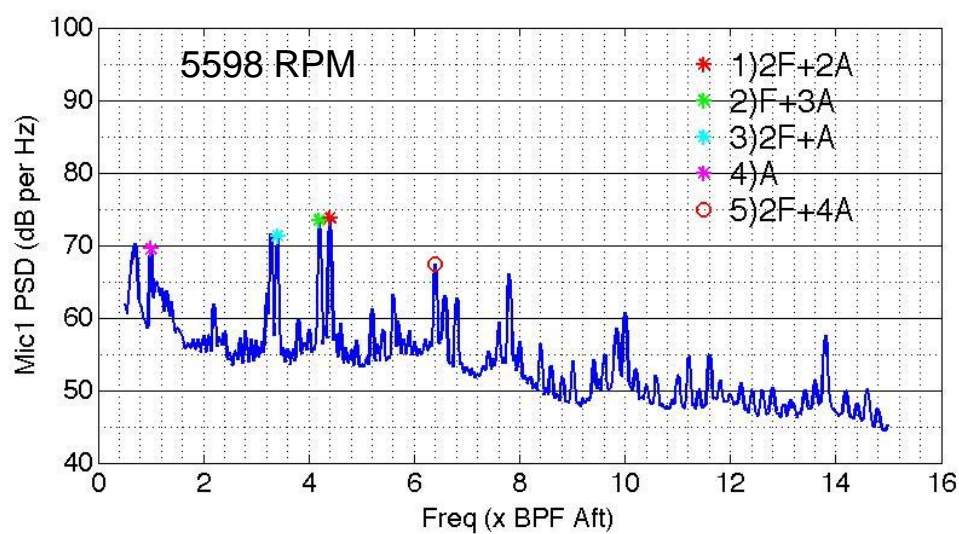
- The interaction tones seem to come from the rotor which has a higher multiple of its BPF in the interaction

# Comparison of Spectra

no pylon vs. pylon

$M=0.2$ ,  $0^\circ$  AOA, approach, varying HP





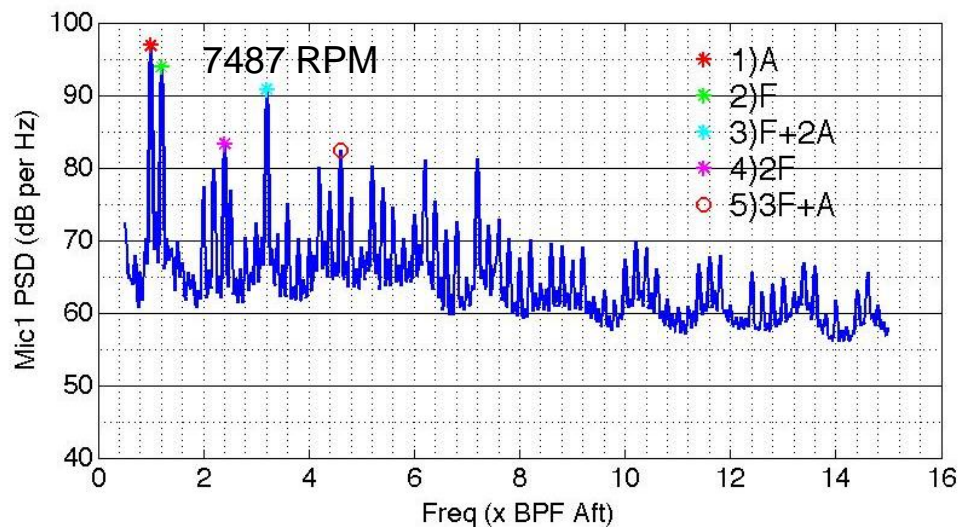
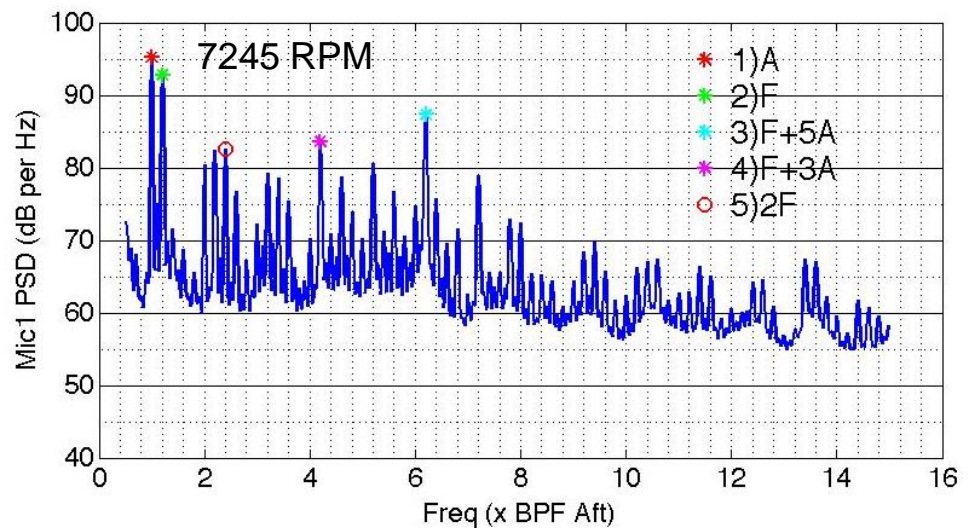
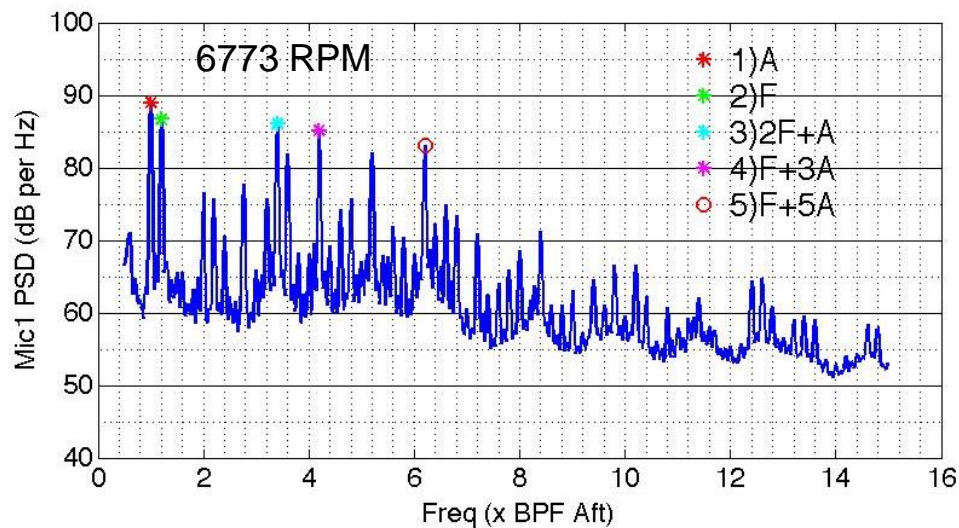
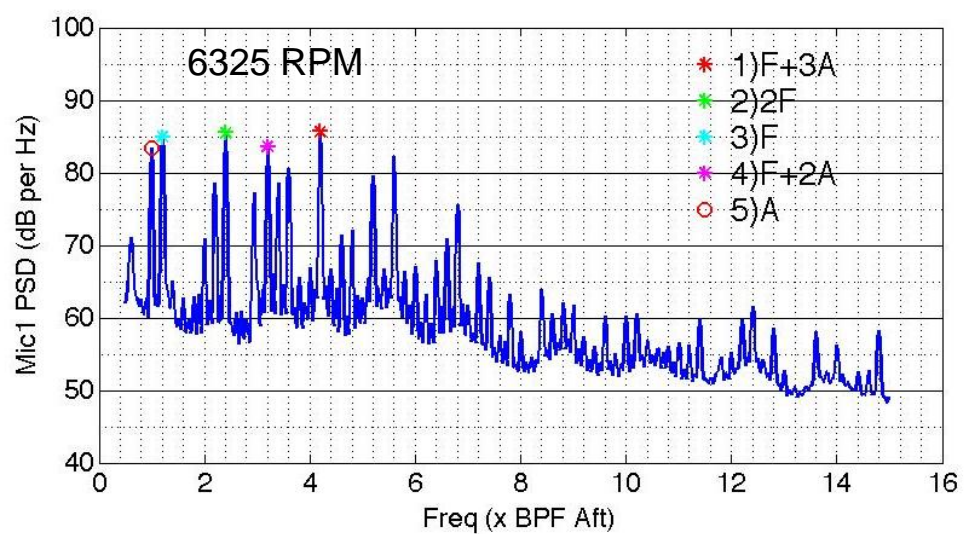
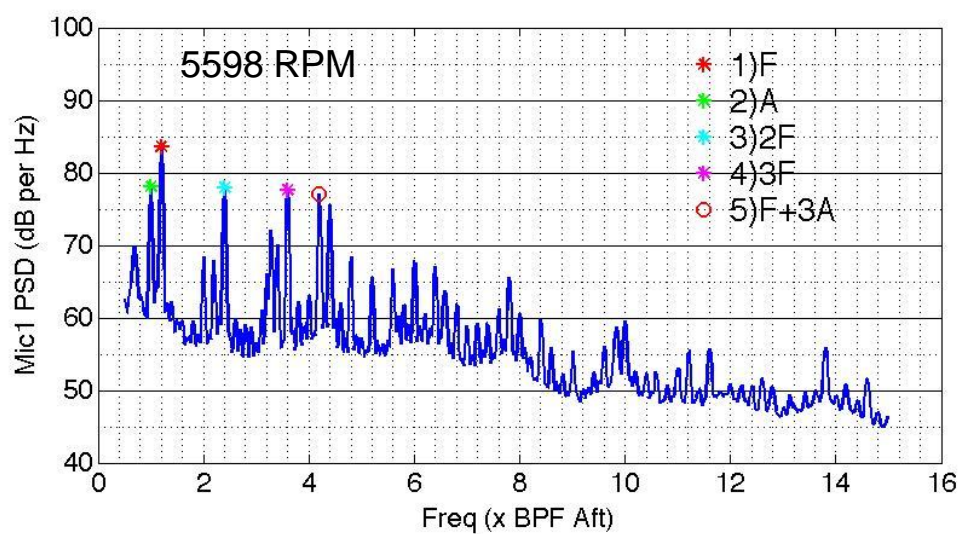
Without the pylon-

BPF tones become more important as HP increases

BPFA > BPFF

At high HP, F+xA interaction tones are important





With the pylon-

Both broadband and tones increase

BPF tones important even at low HP

BPFF > BPFA at low HP, BPFA > BPFF at high HP

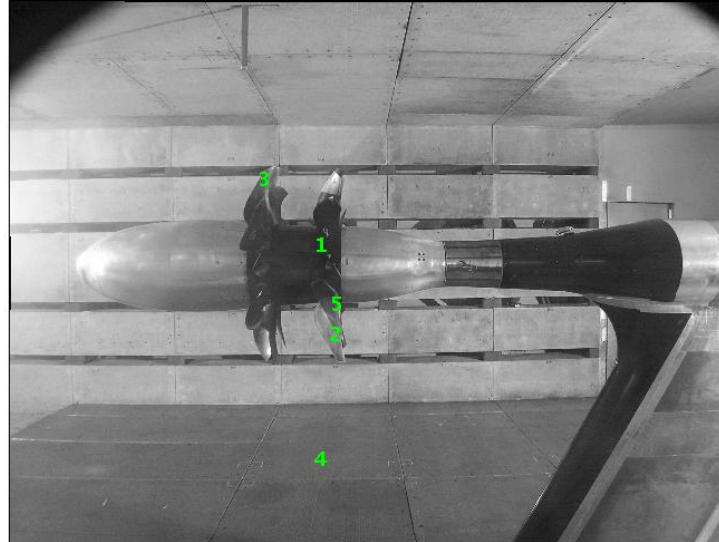
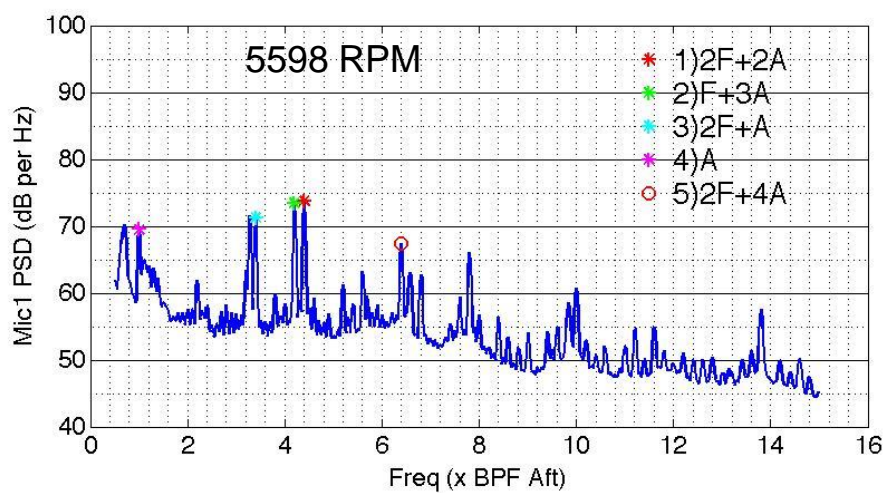
xF tones important at all speeds

# Comparison of Dominant Tone Location

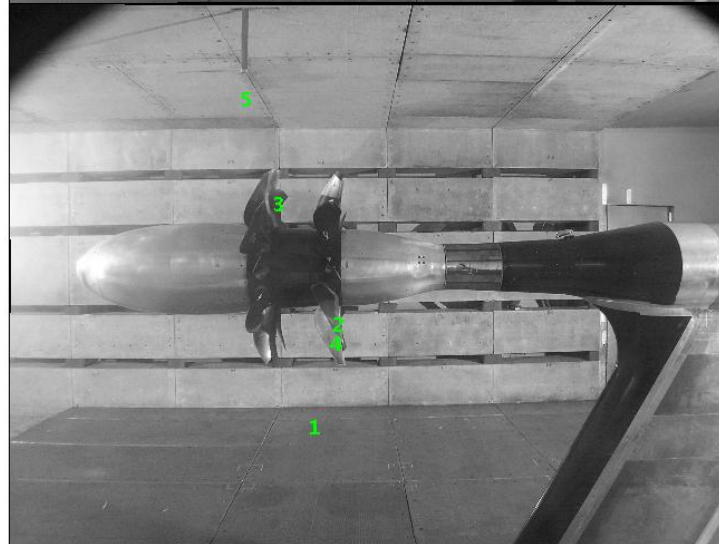
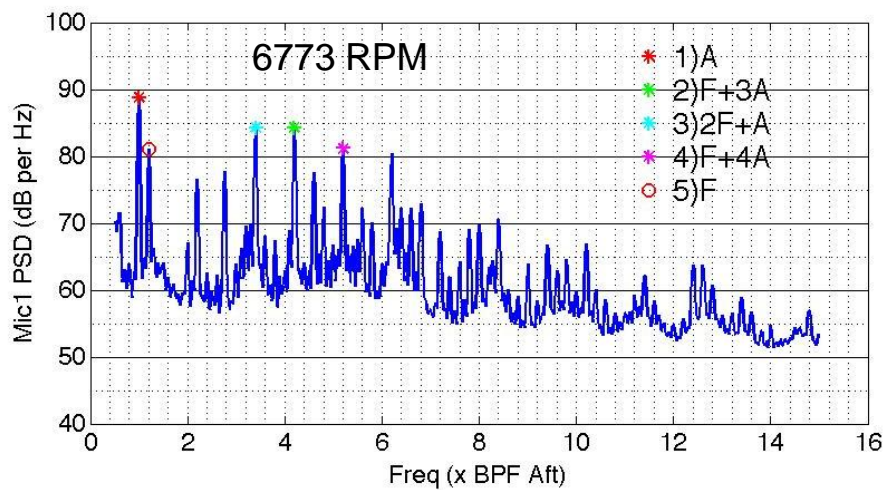
no pylon vs. pylon

$M=0.2$ ,  $0^\circ$  AOA, approach, varying HP

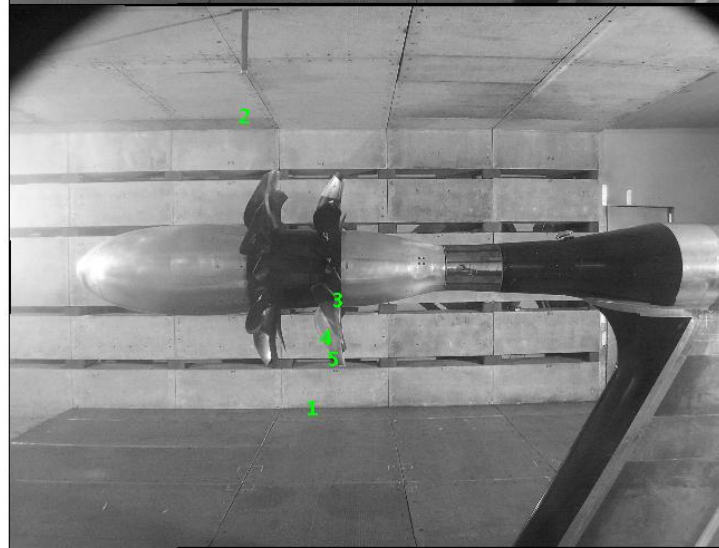
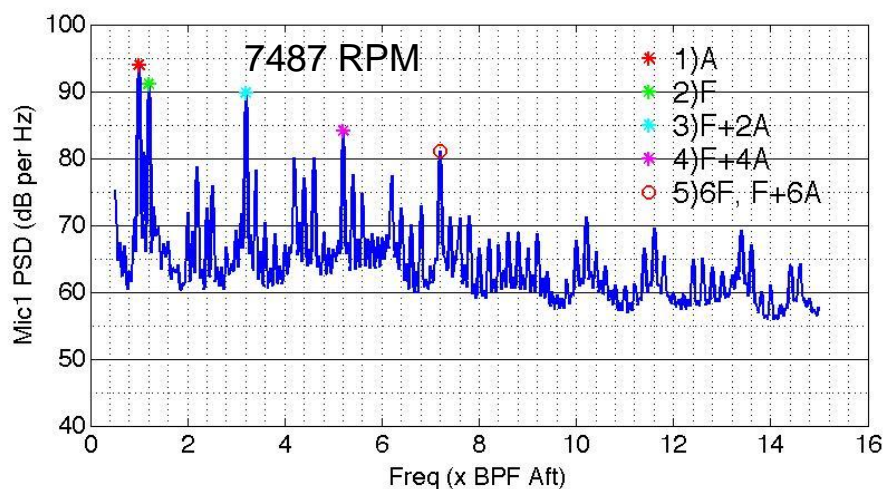




-The dominant tones are, for the most part, located on the side of the rig where the blade is rotating toward the phased array.

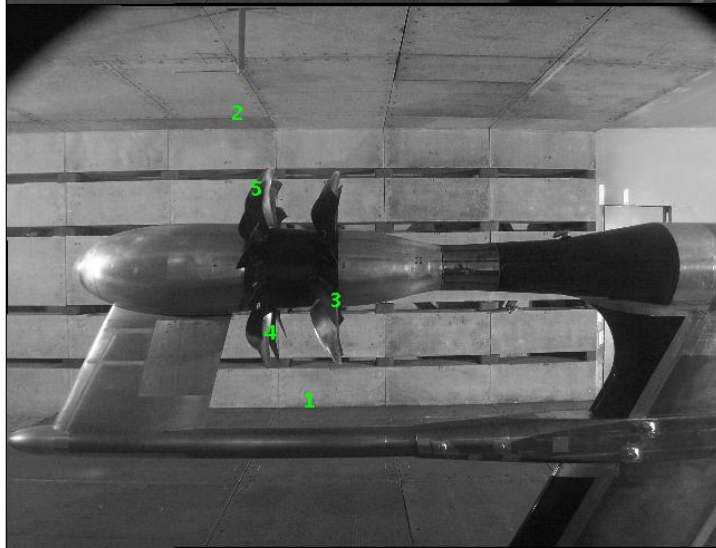
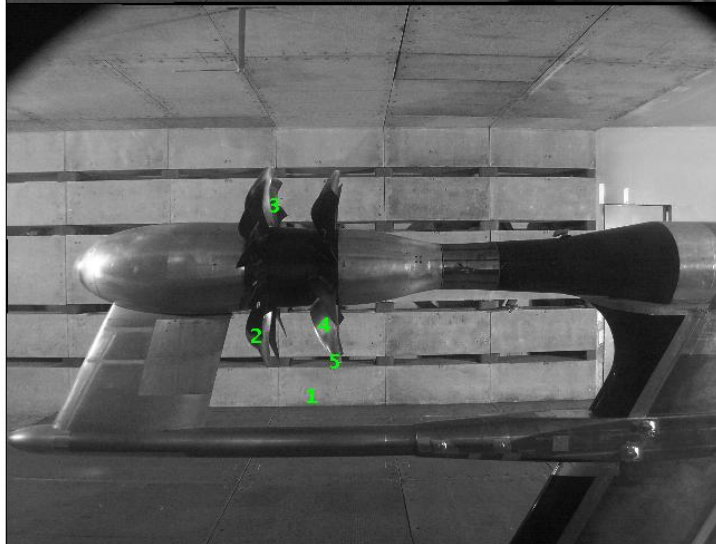
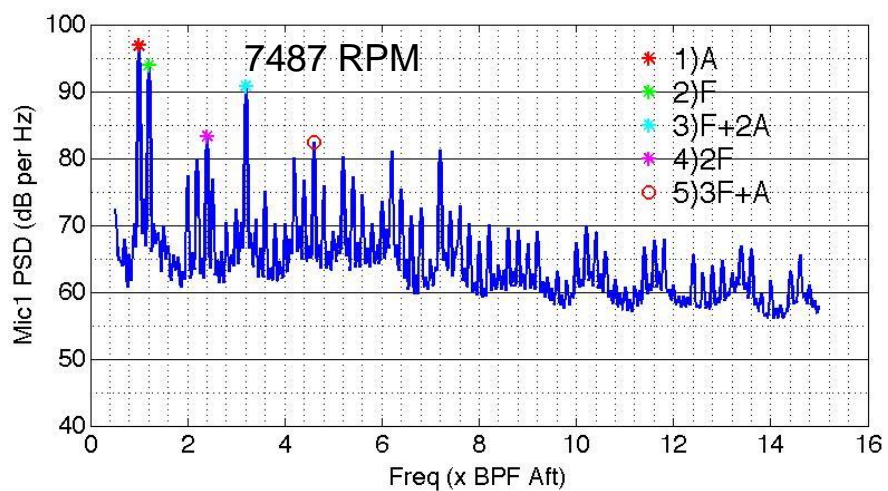
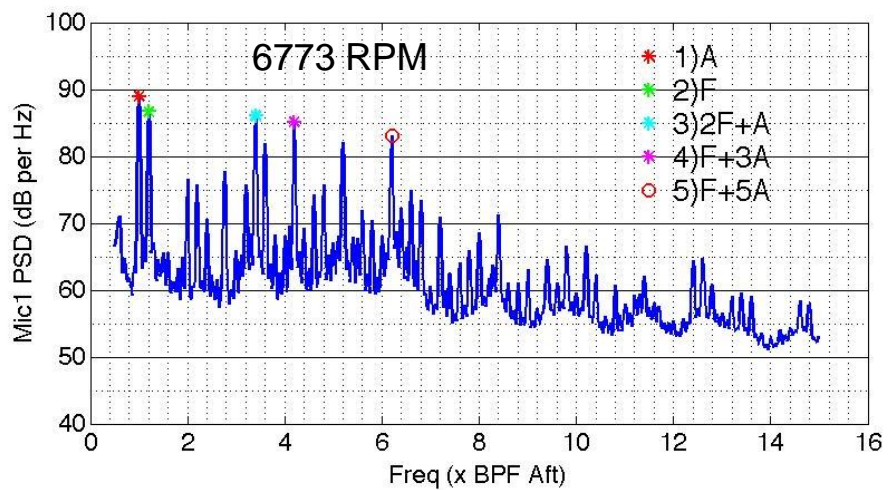
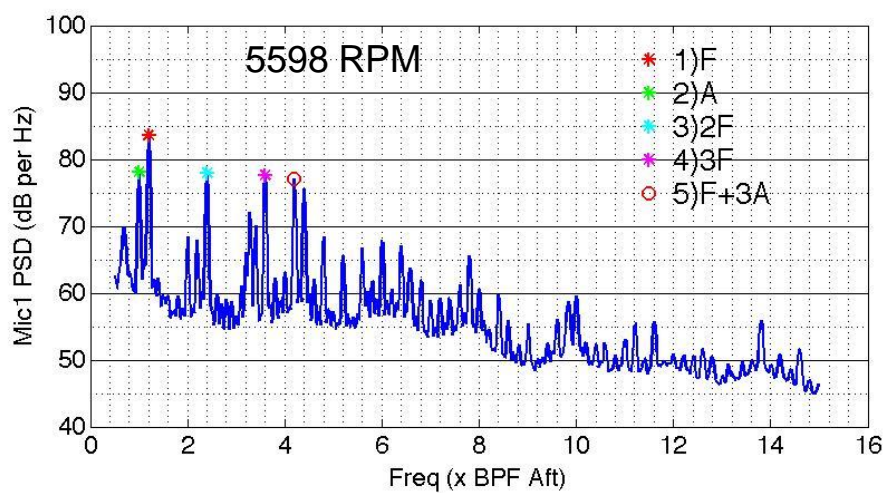


-A large percentage of the dominant tones are located on the aft rotor



- The interaction tones seem to come from the rotor which has a higher multiple of its BPF in the interaction





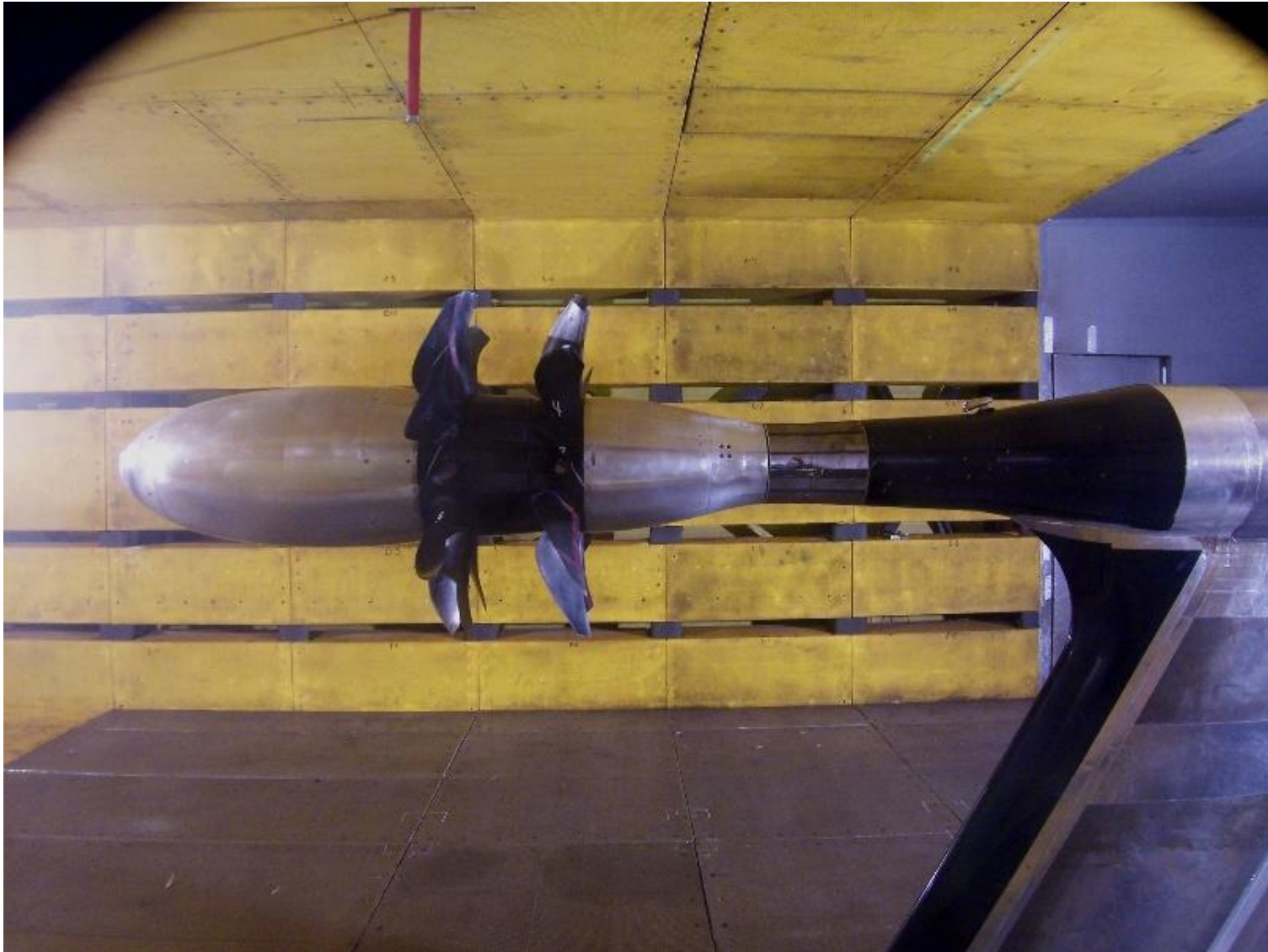
Unlike the no pylon case:

-The dominant tones are located on the lower side of the rig where the blade is passing the pylon, especially at lower HP

-A smaller percentage of the dominant tones are found on the aft rotor

## Regions of Interest

*Can look for noise sources in entire image*





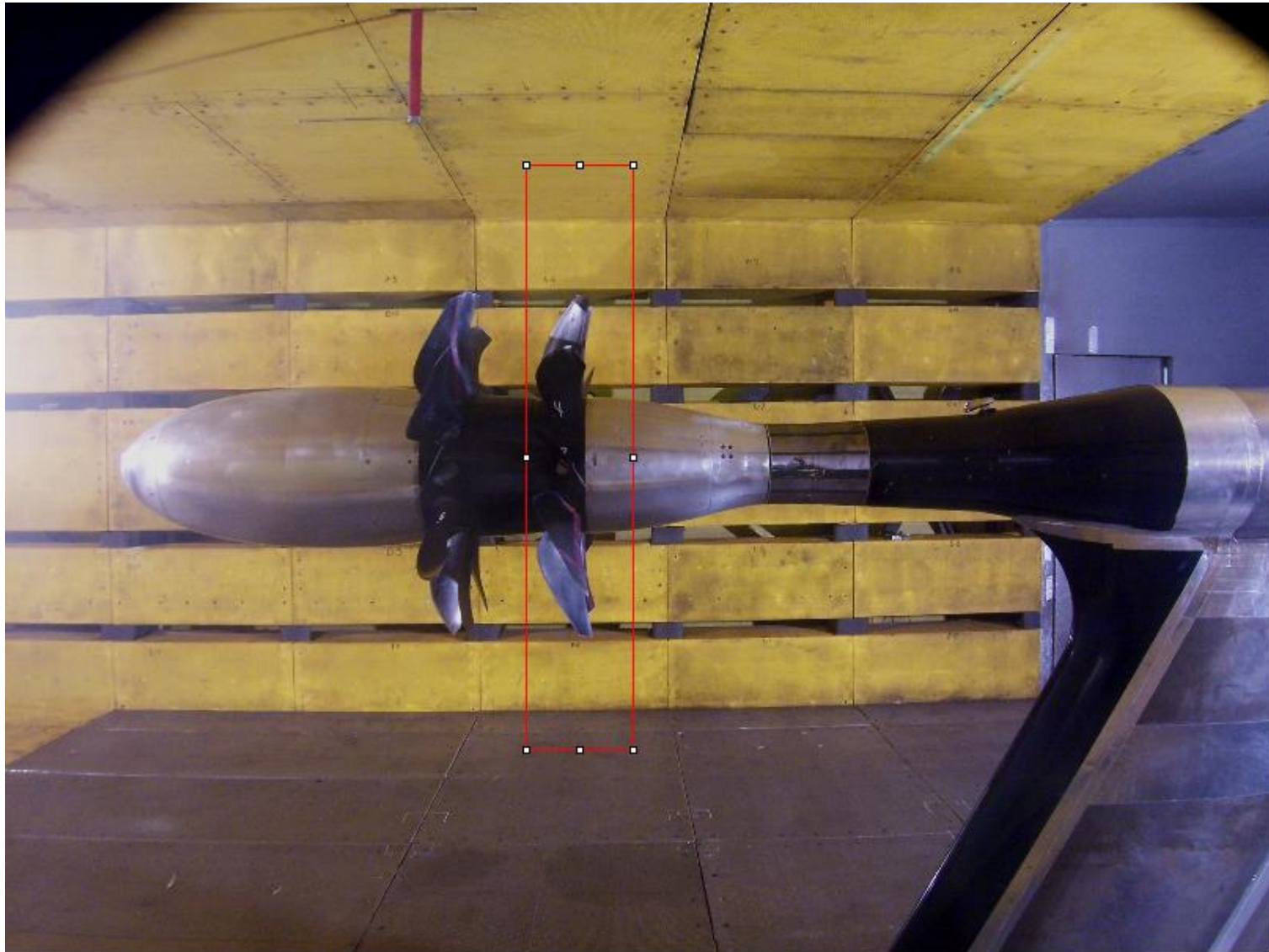
# Regions of Interest

*...or only around the front rotor*

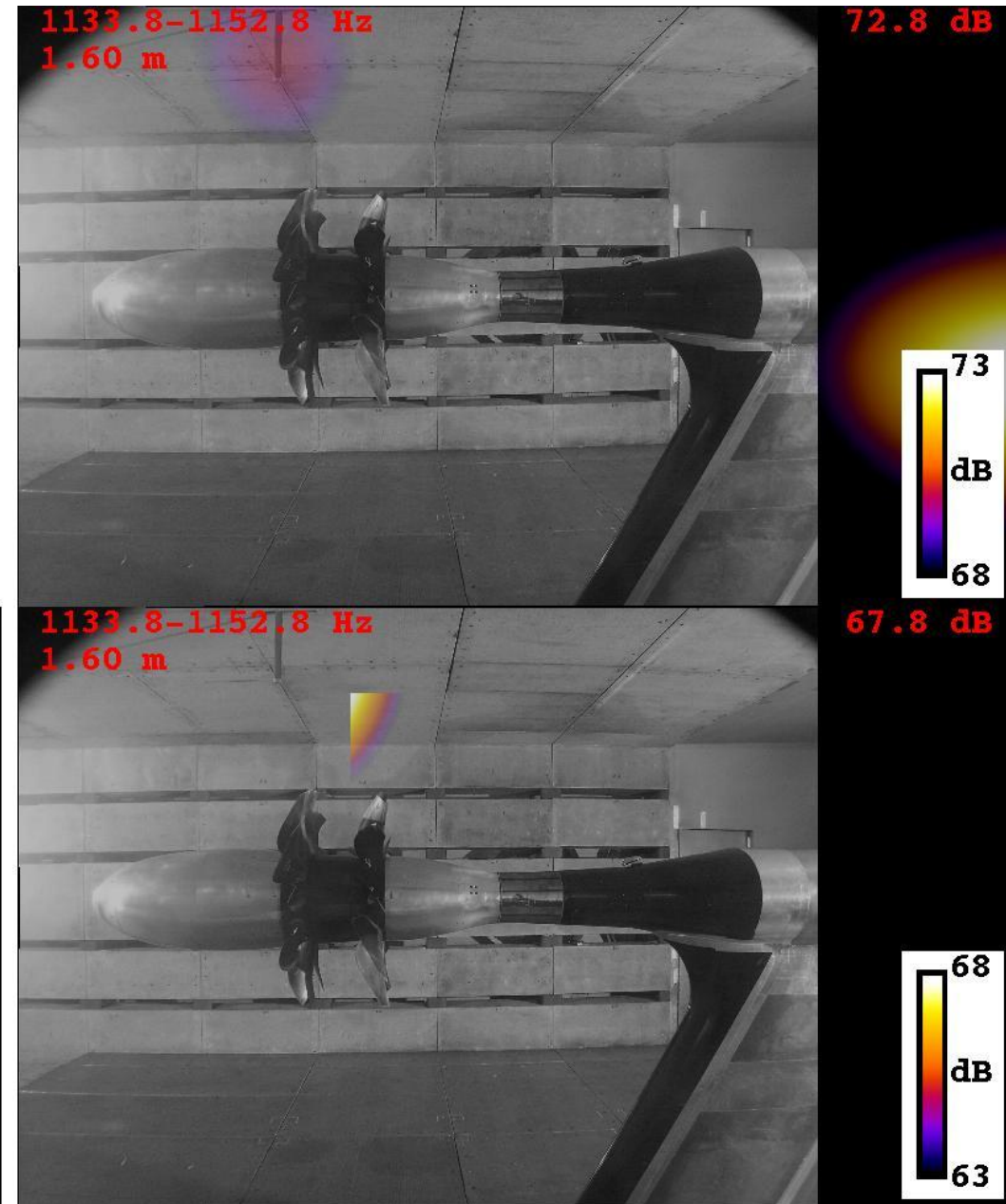
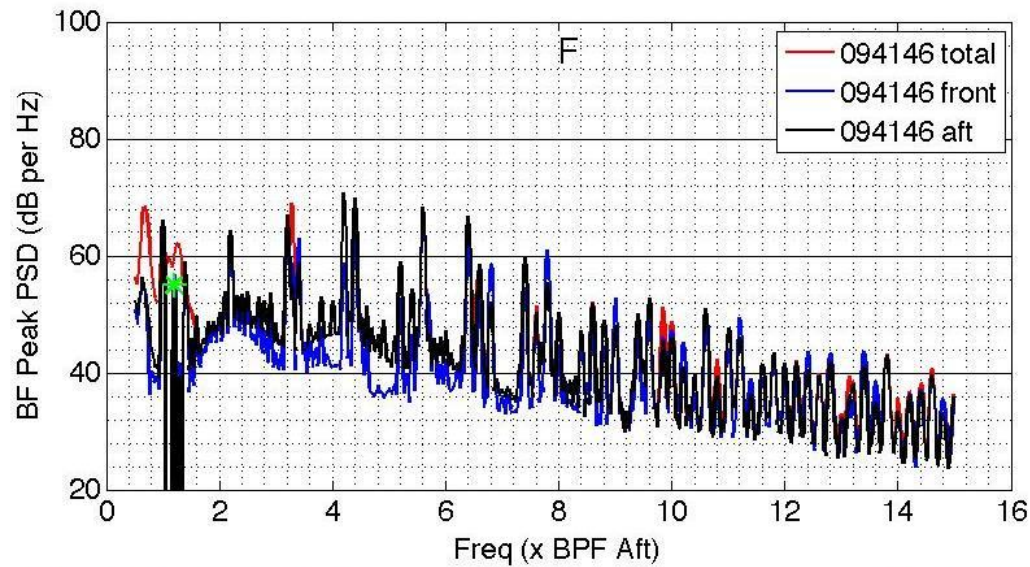




# Regions of Interest *...or only around the aft rotor*



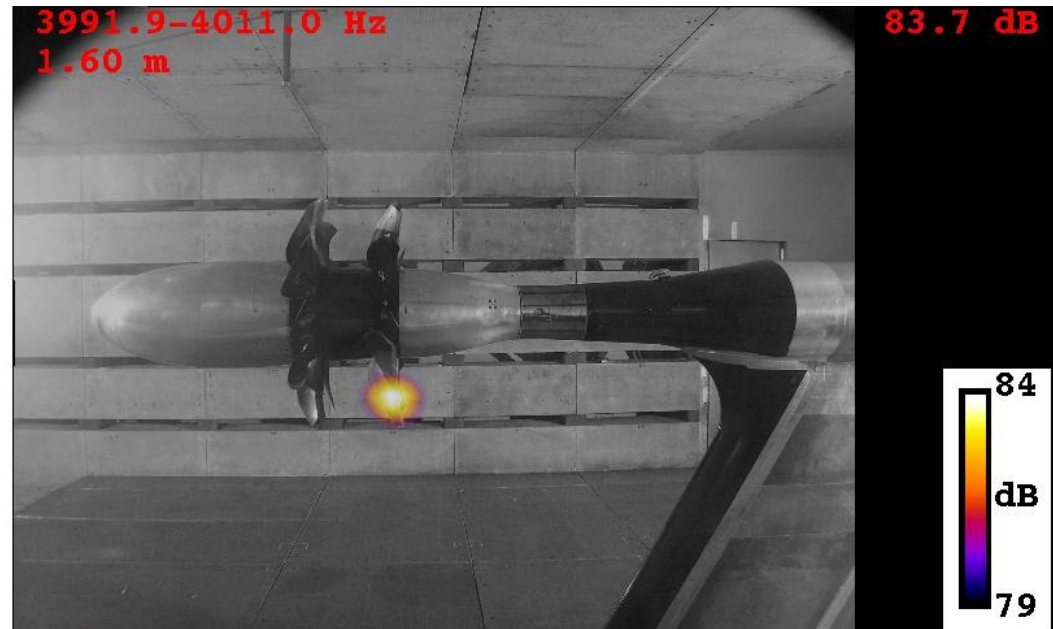
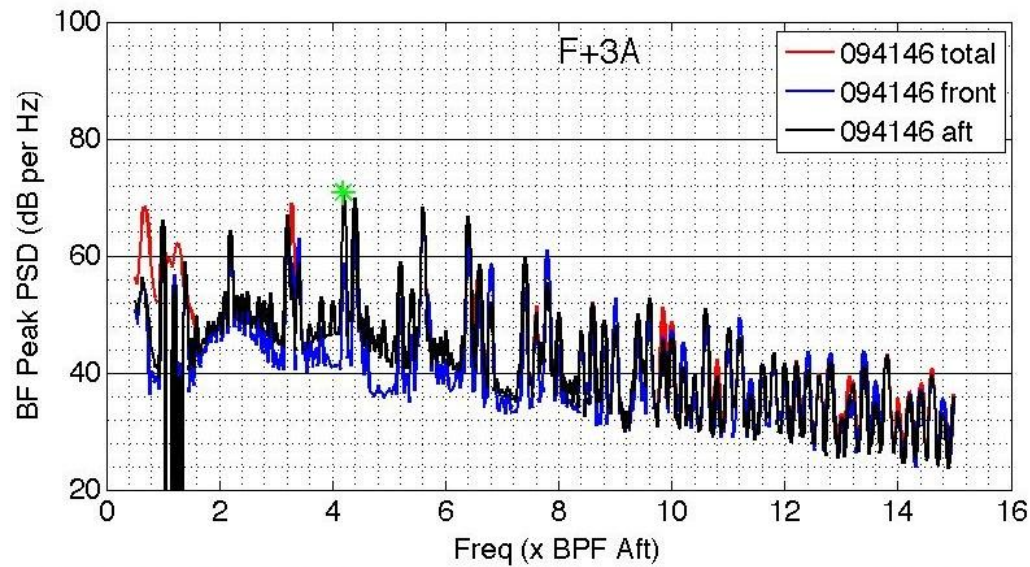
BPFF tone  
No pylon, Approach Blade Angle Settings,  $M=0.2$ ,  $0^\circ$  AOA, 5598 RPM





# F+3A Interaction tone

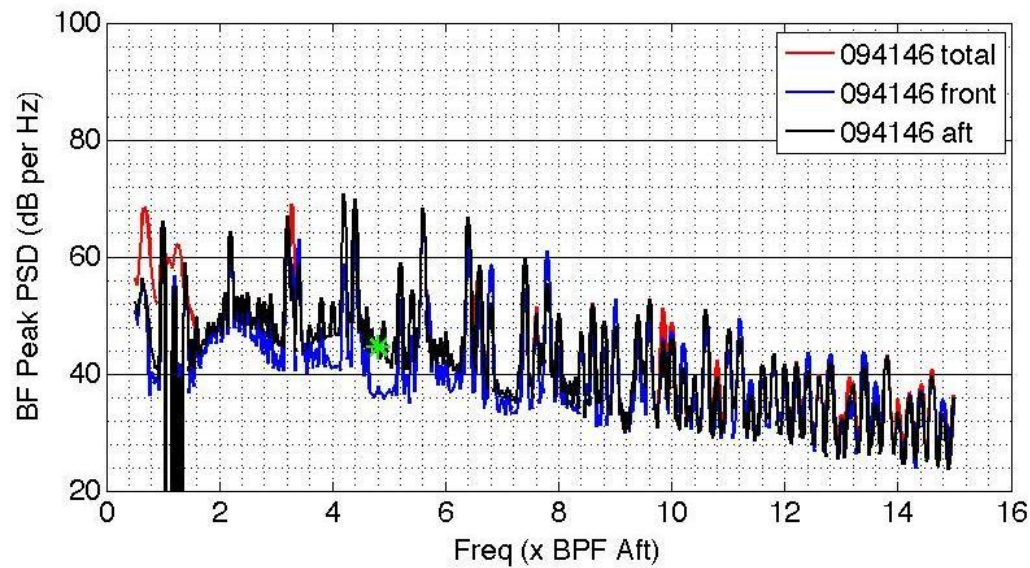
No pylon, Approach Blade Angle Settings , M=0.2, 0° AOA, 5598 RPM





# Broadband noise

No pylon, Approach Blade Angle Settings ,  $M=0.2$ ,  $0^\circ$  AOA, 5598 RPM



# Summary

Phased array data are presented for the GE Counter Rotating Open Rotor Model at  $0^\circ$  AOA,  $M=0.2$ , at the Approach condition blade angle settings.

Without a pylon:

- 1) interaction tones dominate over BPF tones at the design RPM
- 2) more broadband noise comes from the aft rotor than the front rotor at the design RPM
- 3) as RPM increases above the design speed: noise levels increase, more tones appear, and the BPF tones become more dominant.  $BPFA > BPFF$ . At high RPM,  $F+xA$  tones are important.
- 4) the tones tend to come from the side of the rotor rotating toward array (pressure side of the blades). Most tones come from the aft rotor. Dominant interaction tones tend to come from the rotor with the larger multiple in the interaction (ex:  $3F+A$  from front,  $F+4A$  from back)

With a pylon:

- 1) at the design RPM,  $xF$  tones important
- 2) at the design RPM,  $BPFF > BPFA$ . At higher RPM,  $BPFA > BPFF$
- 3) dominant tones located on the lower side of the rig, especially at low HP
- 4) dominant tones more evenly split between the two rotors
- 5) like the no pylon case, dominant interaction tones tend to come from the rotor with the larger multiple in the interaction

